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PRACTICAL MINER'S GUIDE:

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A

TREATISE ON MINE ENGINEERING:

COMPRISING A SET OF

TRIGONOMETRICAL TABLES,

ADAPTED TO ALL PURPOSES OF

OBLIQUE OR DIAGONAL, VERTICAL, HORIZONTAL, AND TRAVERSE

DIALLING,

WITH THEIR APPLICATION TO THE DIAL EXERCISE OF

SHAFTS, ADITS, DRIFTS, LODES, SLIDES, LEVELLING,
INACCESSIBLE DISTANCES, &c.

ALSO,

A TREATISE ON THE ART AND PRACTICE OF ASSAYING METALS, WITH TABLES
WHICH EXHIBIT AT ONE VIEW THE VALUE OF ASSAYED ORES: RULES
FOR CALCULATING THE POWER OF STEAM, WATER, AND
CORNISH PUMPING ENGINES:

QUALITY, MANUFACTURE, AND CHOICE OF CORDAGE AND WIRE ROPE
FOR MINE SERVICE:

ON GASES, VENTILATION, AND LIGHTING OF MINES, BORING ARTESIAN
WELLS, &c., &c.

TOGETHER WITH A COLLECTION OF

Essential Tables, Rules, and Illustrations,

APPLICABLE TO

MINING BUSINESS.

THE WHOLE ILLUSTRATED, INTRODUCED, AND EXEMPLIFIED IN THE MOST
PLAIN AND PRACTICAL MANNER FROM THE LATEST
AND BEST AUTHORITIES.

By
J. Budge

NEW YORK:
PUBLISHED BY G. M. NEWTON,
AT THE OFFICE OF THE MINING MAGAZINE,
1858.

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PREFACE.

THE Practical Miner's Guide, by J.ohn Budge, was republished in the pages of the Mining Magazine during the year 1856, and from the favorable manner in which it was received, the present publisher has been induced to reproduce it with such additions and alterations as seemed requisite to make it still more useful. As now arranged, it will be found to be at once the most complete, reliable, and useful book, to the Practical Miner, in the English language. In making the additions, the best practical authorities have been consulted and referred to, and it would seem proper that they should be mentioned here. "Greenwell's Treatise on Mine Engineering," "Annales des Mines," "Handbuch de Bergbau und Huttenkund, by Carl Hartmann," "Ponson on Coal Mining," "Phillips, Blackwell, Mackworth, and Hopton on Ventilation," "Combe's Traite de l'Exploitation des Mines," "Herbert Mackworth on Artesian Wells," &c., &c.

The great advantage of the diffusion of information of a practical character, is in no branch of industry more clearly apparent than in that of Mining. Its object may be considered two-fold; the first being the instruction of those who are contemplating Mining as a profession, and also those who are at present placed in situations of responsibility, but who, in many instances, know very little of the first principles of subjects with which they ought to be thoroughly conversant.

Throughout this volume the benefit of the Practical Miner has been constantly kept in view, and the tables can be relied upon, and may be received and applied to the most difficult and important operations in dialling, with the utmost confidence. In conclusion, we have generally used such terms as are common to mining operations, believing that this phraseology will render the work far more acceptable to those for whose use it is designed.

EXPLANATION OF THE DIAGRAMS.

TABLE I. Page 45.

In this scheme the hypothenuse is made radius, consequently the other sides are the sine and cosine of the included angle.

Corollary. Suppose one end of the line A B to remain at A while the other end B is moved round from *e* to *f*, then it is evident that the base C B will continue to increase, and the perpendicular B D to decrease, until the whole quadrant has been swept off.

At 45°, or the middle of the quadrant, the base and perpendicular are equal, and from that point to 90° the base will increase in the same ratio as the perpendicular decreased from 1° to 45°; hence the propriety of the arrangement of this table in counting the degrees backward from 45 to 90.

TABLE II. PAGE 51.

Here the perpendicular is made radius, therefore the hypothenuse A C will be the secant, and the base B C the tangent of the angle A. On this principle it is clear, that as the angle increases the base and hypothenuse will continue (throughout the whole quadrant) to increase in proportion.

TABLE III. Page 57.

In this diagram the base is made radius, therefore by mathematical demonstration the perpendicular A C is the co-tangent, and the hypothenuse B C the co-secant, of the angle C; and here it will be plain, that as the angle C is increased, the hypothenuse and perpendicular will, proportionably, be diminished.

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THE PRACTICAL MINER'S GUIDE.

INTRODUCTION.

It is an acknowledged fact, that dialling, in all its varieties, is the most difficult and momentous part of the duty of practical mine agents: to assist them in that important operation, is the chief design in giving publicity to these Tables.

Notwithstanding the great improvements which of late years have been made in the art of dialling, the most intelligent miners universally admit, that the practice is still very imperfect; nay, so far are they from any determinate and general system, that two persons can scarcely be found who precisely adopt the same method; consequently, some plain scheme, founded on pure mathematical principles, is a great mining desideratum.

Aware of the opposition which is so apt to arise against all attempts at innovation of an old and established habit, (which, however faulty in itself, custom may have stamped with an imaginary perfection,) it may be necessary to make a few observations in support of this work, and endeavor to prove its advantages over all the preceding modes of performing a dialling operation in every respect.

Not many years ago, the customary way of ascertaining the perpendicular and horizontal lines corresponding with a diagonal shaft, was by the very uncertain, expensive, and tardy practice of dropping a plumb line from the back to the bottom, there fixing a sollar or platform, and repeating the process from the brace to the foot of the shaft; this usage is largely explained in "Pryce's Treatise on Mines and Mining," (a celebrated work, published by subscription, about the year 1776,) and therein described as the only system then known.

It is true this most objectionable measure is now exploded, but not without great reluctance by many of its old practitioners, who were long before they could be prevailed on to abandon it, notwithstanding its glaring inconveniences, accompanied with the loss of time, waste of property, and hazard of their lives.

By inserting this defectibility of our predecessors, we have no other design than of cautioning our mining countrymen to guard against the too prevalent propensity of rejecting any new system, merely because it is *new*, or its utility not discerned at first sight; and to induce them to give the subject an impartial investigation, before they pass a conclusive judgment thereon.

The use of mathematical instruments is now partially known in the mining world; and, certainly, those agents who are well acquainted therewith, possess a decided advantage over others who are not; for, doubtless, this science has the pre-eminence, in a high degree, over every other method heretofore employed in dialling. But without intending to undervalue instrumental operation, we appeal to the experience of our scientific readers for support, in avouching that the process is ever liable to errors of considerable extent, and which are prone to slide in unaccountably: but it is a palpable fact, that in pointing or sweeping off the angles, an almost imperceptible deviation will create a serious departure from truth; and even in the course of bisecting, trisecting, inscribing, describing, and circumscribing; also in drawing parallels, raising or demitting perpendiculars, the operation, even with the greatest care, is exposed to considerable mistakes: and so sensible are all professional men of this defect, that instrumental operation is never resorted to, or relied on in any case where great accuracy is required. But when we reflect on the laborious duties of the practical mine agent, and how much these duties are calculated to disqualify him for performing a geometrical plan with that delicacy and precision which the operation so indispensably demands, we then become established in our opinion of the necessity of a work of this kind, and of its superiority over every other system hitherto introduced in dialling.

Should any be yet disposed to advocate the existing practice, and to contend that it is fully adequate to the desired purpose, we beg permission to inquire of such persons, why it is that mistakes so commonly occur in sinking shafts and driving levels in most of our mines? That irreparable errors do frequently happen, is a truth too notorious for contradiction or dispute, and sometimes even under the superintendence of men, whose knowledge, circumspection, and experience, no one presumes to call in question; consequently a more convincing proof than this cannot be adduced of the fallibility of the best modern practice, and the necessity for the introduction of a more perfect system.

Should it be inquired wherein the merit of this work is considered to consist, we answer, First—*Accuracy;* and it will be discovered at a glance, that every operation of the principal tables is wrought out to five places of decimals, or the *ten thousandth part of an inch!* consequently we may affirm, without fear of confutation, that, in this property, we outvie every other system.

Secondly—*Plainness.* Of this quality our expert readers will be convinced at first sight, and will need no instruction for enabling them to apply the numbers readily; but we do not hesitate to say, that, by the help of the rules and examples, a common school-boy will find no insurmountable difficulty in solving the most abstruse problems relevant to dialling.

Thirdly—*Despatch.* To this desirable property no other system has an equal claim, or can, with any chance of success, enter into competition with our method; inasmuch as an answer, in most cases, may be obtained by the tables in less time than is necessary to make a preparation for performing the operation in any other way.

And now having briefly endeavored to set forth the work in a true light, we commit it to the judgment of a liberal and discerning people; and should it be instrumental in happily preventing the grievous errors which are so prevalent in mining operations (and which, we are bold to say, must, in the nature of things, continue to take place by the present day practice); or should it only help to relieve the minds of faithful superintendents from that painful anxiety and suspense which never fail to harass them during the progress of any considerable work, whereby a heavy responsibility rests on them for the accuracy of their dialling; or should it in any other way have the happy tendency of promoting the interest of mining, we shall not regret the labor, pain, expense, privation, trouble, and perplexity, it has cost us, even though we should never receive any other compensation.

EXPLANATION AND USE OF THE TABLES.

After so many preliminary observations, it will be necessary to say but little under this head, having already anticipated several things by way of introduction, which properly belong here.

The reader will observe that the work is composed of three distinct tables, for the obvious reason of making each side of the triangle radius; and certainly without such an arrangement it would have been incomplete.

In each case the radius, or given side, is one fathom, being the most convenient and familiar proportion that could have been introduced.

The principal calculations include every quarter, or fifteen minutes of a degree, and extend from 1 to 89 degrees, being sufficiently extensive and minute for mining purposes (the angle of any intermediate division not being distinguished or required); and here, it must be observed, that the divisions are expressed by 15, 30, and 45 minutes, which numbers represent $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ of a degree.

The first and most essential table is that wherein the hypothenuse, or longest side, is made radius, extending nearly throughout the quadrant, and every calculation wrought out to five decimal places of an inch, hereby giving a direct answer, in exact ratio to six feet of the given side, to the ten thousandth part of an inch.

Perhaps there may be a little difficulty at first, with persons unacquainted with mathematical order, in reading the first table. It must be remarked, that from 1° to 45°, or the middle of the quadrant, the degrees and parts are all on the left-hand side descending, the base stands in the adjoining columns, and the perpendicular on the same line to the right; but beyond that point the degrees will be found on the right-hand side ascending, and then it must be specially noted that the perpendicular and base will have changed their positions, the base now standing on the right hand, and the perpendicular on the left hand, side.

In the second table the perpendicular is given and the angles extend to 60°. One valuable mining property of this table is, that it gives at sight the underlay in a fathom of every angle within the range of 60°, including the divisions: so that if it is required to know the underlay in a fathom on any degree, or quarter of a degree, between 1 and 60, it will be immediately discovered by an inspection of the base in the column adjoining the given angle in this table.

In the third and last table the base is given, and as the application of this part of the work is not so general as the preceding, the angles have been given in degrees only: nevertheless this table is indispensable on some occasions, especially in levelling or driving adits. It will be found, like the second table, to extend from 1 to 60 degrees.

Having thus briefly stated the nature of the work under each separate head, it only remains for us, after a few general observations, to recommend the learner to the inspection of the following examples; for we believe that one practical operation will do more towards giving him a clear understanding or comprehension of the subject, than a volume written expressly thereon, confined to mere speculative description.

It may be remarked that, in almost every instance, the geometrical construction of the figure is introduced, with the calculation, which will tend to the satisfaction of the practitioner, and improvement of the beginner.

In conclusion we would remark, that the same attention must be paid in taking the angle, and measuring the given line, when these tables are used, as if the operation was performed any other way.

It is a common practice in mining to take the angle of underlaying shafts with the cover of the dial and a plumb-line; and in short drafts, with great care, this method may answer well enough: but when any very important work is to be performed, we would strongly recommend the application of a more perfect instrument for ascertaining the angle; for it is well known, that if this part of the process should not be correct, the result of the whole work must be erroneous as a matter of course; and indeed it is next to impossible to distinguish the minutia of an angle, with any tolerable degree of certainty, by the foregoing method. There doubtless are instruments much better adapted to the work, both for speed and accuracy, than the dial; and it is matter of surprise that they have not been more generally introduced in our mines: of these instruments the Theodolite certainly stands unrivalled for taking both horizontal and vertical angles.

It is not our design to enter into controversy on this subject; those who imagine the sextant or quadrant graduated on the cover of the dial well calculated for the purpose, let them continue to use it; only we would especially note, that should an error ensue, it ought by all means to be attributed to the real cause, and to that only: for, as in all trigonometrical questions, the angle and side are always given to find the other parts of the triangle, consequently the sum of the one and length of the other are presupposed to have been correctly ascertained, previous to the commencement of any other operation.

Finally, for the learner's sake, we observe, that as the tables exhibit only the relative proportions to the radius of one fathom, or six feet, and are wrought out to five places of decimals to an inch, it becomes necessary that every one who would use this work successfully should have some knowledge of decimated arithmetic; because he will have, in most cases, to multiply for the whole numbers, and take parts for the fraction of the fathom· For example: suppose the given side to be the hypothenuse, measuring 16 fathoms, 3 feet, and 6 inches, he will then have to take out the numbers opposite the given angle in the tables, and multiply them by 16, for the base and perpendicular respectively, then divide half the tabular measure for the 3 feet, and one-sixth of the remainder for the 6 inches, and add them together for the sum of the required sides of the triangle. We have therefore introduced the following rules and examples in decimals, which are sufficient to enable any one, hitherto unacquainted with this branch of arithmetic, to use the tables with the greatest facility.

REDUCTION OF DECIMALS.

Rule.—Multiply the decimal by the number of parts in the next less denomination, and cut off as many places to the right hand as there are places in the given decimals.

EXAMPLE.

What is the value of ·75014 of a fathom?
6

4·50084
12

6·01008

ft. in.
Answer 4 6·01008

What is the value of ·93862 of a yard?
3

2·81586
12

9·79032

ft. in.
Answer 2 9·79032

What is the value of ·27734 of a foot?
12

3·32808

in.
Answer 3·32808

fath. ft. in.
Reduce 5 4 6·32 to feet, inches, and decimals.
6
— in.
Answer 34 6·32
—

ADDITION OF DECIMALS.

Rule.—Place the numbers so that the decimal points may stand directly under each other, add up as in simple addition, and cut off for decimals, as many figures to the right as there are decimals in the greatest given number.

EXAMPLE.

What is the sum of 3·72 and 14·7368 and 146·2 and ·728 and 5·034?

3·72
14·7368
146·2
·728
5·034

170·4188

	ft.	in.	ft.	in.
What is the sum of	2	11·9942 and	1	4·09658?
	1	4·09658		
	4	4·09078		

Add together the following measures, viz.:

fath.	ft.	in. dec.
6	4	2·260
0	1	11·47298
19	0	3·087
64	5	9·9746
0	0	2·70643
91	0	5·50101

SUBTRACTION OF DECIMALS.

Rule.—Arrange and cut off the decimals as in addition.

EXAMPLE.

	fath.	ft.	in.
From	4	2	9·7824
Take	2	4	8·91773
	1	4	0·86467

MULTIPLICATION OF DECIMALS.

Rule.—Multiply as in whole numbers, and cut off as many figures from the product as there are decimals in the multiplier and multiplicand.

EXAMPLE.

	fath.	ft.	in.	
Multiply	2	4	7·92486 by 24	
			6	
	16	3	11·54916	
			4	6 × 4=24
	66	3	10·19664	

	fath.	ft.	in.
Multiply	9	3	1·4872 by 37
			6
	57	0	8·9232
			6
	342	4	5·5392
	9	3	1·4872
	352	1	7·0264

Here we multiply by 6 twice because 6 times 6 are 36, and add the given number which makes it equal to 37, or 6 × 6+1=37

	ft.	in.
Multiply	14	9·746 by 12
		12
	177	8·952

DIVISION OF DECIMALS.

Rule.—Divide as in whole numbers, and cut off as many figures in the quotient as the decimal places in the dividend exceed those of the divisor.

EXAMPLE.

```
         fath.  ft.  in.
Divide    2     4    3·7 by 6
       6) 2     4    3·7
         ----------------
          0     2    8·61
         ----------------

fath. ft.  in.              fath. ft.  in
7) 4   2   10·80994         8) 15  5   0·3316
   -------------            ---------------
   0   3   10·04427             1  5   10·5414
   -------------            ---------------
```

ALIQUOT PARTS OF A FATHOM.

Parts.		Feet.	Inches.
½	of a fathom is	3	0
⅓	ditto	2	0
¼	ditto	1	6
1-6	ditto	1	0
1-8	ditto	0	9
1·9	ditto	0	8
1-12	ditto	0	6
1-16	ditto	0	4½
1-18	ditto	0	4
1-24	ditto	0	3

REMARKS.

It has been observed that the radius in every case is 6 feet or 1 fathom, consequently the number of fathoms in the given side, whether that side be hypothenuse, perpendicular, or base, will be the multiplier of the tabular numbers, and should there be a fraction in the multiplier, the multiplicand must be divided by that fraction agreeably with the rule of practice. The table of aliquot parts of a fathom, in the adjoining page, will be found useful in facilitating this part of the process.

In some of the following examples the product has been obtained in fathoms and parts; but we would recommend the learner to carry on the work in *feet* (except in cases where the answer is required in fathoms), as he will find it more simple and expeditious; we speak of the *multiplicand* or number *multiplied;* the *multiplier* must invariably be fathoms, and should the given side be nominated in feet, it must be divided by 6, to bring it into fathoms, before the operation is begun by the foregoing cases.

It may be further noticed that when any of the given sides in the tables amount to 6 feet, they are expressed in fathoms, &c.; but whenever it may be required to produce the answer in feet, &c., the numbers should be reduced to that measure before they are multiplied, and this can be done by mere inspection; viz.:

		fath.	ft.	in.			ft.	in.
Table 2d, 52°	Base	1	1	8·1560	state	Base	7	8·1560
	Hyp.	1	3	9·6053		Hyp.	9	9·6053

PRELIMINARY CHAPTER

TO THE

PRACTICAL DIALLING EXAMPLES.

It must have been matter of regret to every reflecting well-informed, and interested person, that (previous to the present work) nothing has ever been published with a design to assist the miner in his subterraneous operations; and while the press has teemed with publications, distinctly and exclusively adapted to benefit the navigator, the architect, the sculptor, the surveyor, and even the mechanic and artisan, not a single effort has ever been made to extricate the miner from the disadvantages under which he has ever labored, (solely for the want of a plain, concise, technical, and scientific treatise on dialling, accompanied with appropriate tables,) although his profession yields to none in importance and utility; in fact, it may be said, in a certain sense, to be the parent of every art and science in the world; the use of metallic substances, in some shape or other, being indispensable in every one of them: nevertheless this highly essential art has hitherto been totally disregarded by all classes of mathematicians, and while the famous invention of logarithms has caused the science of trigonometry to soar to the very skies, and traverse old ocean's vast and unfathomable expanse, the unsupported miner has been left to struggle under the greatest disadvantages, with nearly as little obligation to geometrical science, as his antediluvian progenitors; and although he has done every thing that deep thought, strong natural understanding, unwearied perseverance, and inventive genius (unassisted by trigonometrical demonstration) could possibly accomplish, yet, for the want of mathematical light, his exertions have been ineffectual and insufficient to disentangle him from the difficulties with which he has been encircled; hence his avocation has, in general, been replete with toil, anxiety, apprehension, dissatisfaction, and disappointment.

How far the present work is adapted to answer the great end in contemplation, must be left for the judgment of the mining world to decide; and we doubt not but the defects (real or imaginary) which may be considered to exist in the application, will be passed over and excused by every liberal man, on the grounds already stated in the preface; having an unshaken confidence that the fundamentals of the work, comprised in the trigonometrical tables, will be found plain, true, and unexceptionable.

Definition of Right-angled Triangles.—In order to use the following tables with due effect, there is no necessity that the reader should understand any thing of the science of trigonometry, that part of the work having been accomplished already to his hand; so that, by the help of a few of the common rules of arithmetic, he may obtain, with the greatest ease and certainty, every thing required to be known in the geometrical part of mining.

Previous to an elucidation of the simple method of working by the tables, it may be satisfactory to introduce the operation by a few preliminary observations and extracts on the nature and properties of right-angled triangles.

Plane trigonometry is the art of measuring the sides and angles of triangles described on a plane surface, or of such triangles as are composed of straight lines.

The theory of triangles is the very foundation of all geometrical knowledge, for all straight-lined figures may be reduced to triangles. The angles of a triangle determine only its relative species, and are measured in degrees, minutes, and seconds; but the sides determine its absolute magnitude, and may be expressed in fathoms, yards, feet, or any other lineal measure.

Theorems.—A right-angled triangle (the only kind generally necessary to be treated of for mining purposes) is that which has one right angle in it; the longest side, or that opposite to the right angle, is called the hypothenuse, the other two are called the legs or sides, or the base and perpendicular: or, by Euclid's definition, "In a right-angled triangle, the side opposite to the right angle is called the *hypothenuse*, and of the other sides, that upon which the figure is supposed to stand is called the *base*, and the remaining side the *perpendicular*."

The three angles of every triangle are together equal to two right angles, or 180 degrees.

The greater side of every triangle has the greater angle opposite to it.

The squares of two sides of a triangle are together double of the square of half the base, and of the square of a straight line drawn from the vertex to bisect the base.

The sum of the three angles of every plane triangle being equal to half a circle, or 180 degrees, it therefore follows that if either acute angle, in such triangle, be taken from 90°, the remainder will be the other acute angle, or the complement.

The supplement of any angle is what that angle wants of 180°; hence the supplement of any one angle is always equal to the sum of the other two.

A few other properties of right-angled triangles may be worthy of notice, viz.: when the angle opposite the base is 30°, the hypothenuse is exactly double the length of the base.

When the angles are 45°, the base and perpendicular are equal.

When the angle opposite the base is 60°, the hypothenuse is double the length of the perpendicular.

Application.—To show how a knowledge of the foregoing theorems may be rendered useful in mining practices, suppose in the triangle A B C, on page 16, the base B A represented a drift or cross-cut, and the side A C a lode, making an angle with the base of 66° 30′; consequently the angle A must be 23° 30′, because it requires that number of degrees to constitute a right angle, the complement of the angle A, or 180°, the supplement of the triangle A B C.

Again, suppose the angle C of the diagonal shaft C A, page 17, was found to be 39° 30′, then the opposite angle A must contain 50° 30°.

We now approach towards the actual use of the tables, and have succeeded, we hope, in clearing all impediments out of the learner's way, so that he will find no difficulty in readily applying the numbers to dialling operations. We have previously set a few examples of the mere act of taking out the primes, and have studiously endeavored to render every thing so perspicuous and comprehensible as the nature of the work would possibly admit. But should any one have gone thus far and still find an obscurity hang over him, so that he cannot penetrate into the nature of the subject as he would wish, or as he may have expected, yet let him not be discouraged; this will always be the case with every one who calculates on fully comprehending any thing connected with the mathematics by definition or description only. Let him steadily, attentively, and perseveringly proceed with the examples, and if he is properly interested in the matter, he will soon find the subject open with perspicuity and demonstration on his mind, and convey to him the incontrovertible assurance of the truth of the calculations, as well as the correctness of his own views, ideas, or conceptions of the subject.

TABLE I.—EXAMPLE.

When the angle is 9° and the hypothenuse 1 fathom, what is the length of the other two sides of the triangle respectively?

(See first table, second page.)

	in.		ft.	in.
Answer, Base	11·26328	Perp.	5	11·11356

EXAMPLE.

When the angle is 48° 15′, or 48¼ degrees,* and the hypothenuse 1 fathom, what are the lengths of the other sides?

(See first table, last page.)

	ft.	in.		ft.	in.
Answer, Base	4	5·71613	Perp.	3	11·94348

TABLE II.—EXAMPLE.

When the angle is 35° 45′ or 35¾ degrees, and the perpendicular 1 fathom, what is the length of the hypothenuse and base respectively?

(See second table, third page.)

	ft.	in.		fath.	ft.	in.
Answer, Base	4	3·8326	Hyp.	1	1	4·7165

EXAMPLE.

Given the angle 59° 30′, perpendicular 1 fathom, the other sides are required.

(See second table, third page.)

	fath.	ft.	in.		fath.	ft.	in.
Answer, Base	1	4	2·2317	Hyp.	1	5	9·8612

---

* In this example, as the angle exceeds 45°, it will be found standing on the right hand side of the page (as already explained), and the denomination of the required sides will be found at the bottom. A little attention to this order will prevent the mistake, which may otherwise take place, by an inversion of the base and perpendicular.

TABLE III.—EXAMPLE.

Given the angle 5°, base 1 fathom, the hypothenuse and perpendicular are required.

(*See third table, base radius.*)

	fath.	ft.	in.		fath.	ft.	in.
Answer, Hyp.	11	2	10·10734	Perp.	11	2	6·96874

EXAMPLE.

Given the angle 30°, base 1 fathom, the other sides are required.

(*See ditto.*)

	fath.	ft.	in.		fath.	ft.	in.
Answer, Hyp.	2	0	0	Perp.	1	4	4·70766

NOTE.—The foregoing examples serve only to exemplify the manner of taking out the primes from the tables, and as the given side is exactly one fathom, of course the tables give a direct answer. In the following examples the mode of taking out the tabular numbers is precisely as the foregoing, but the number of fathoms contained in the length of the given side, will be the multiplier of the other sides of the triangle.

PLANE TRIGONOMETRY.

BY THE TABLES.

CASE I.—WHEN THE HYPOTHENUSE IS GIVEN.

Rule.—Look in the first table, and against the given angle stands the base and perpendicular, answering to one fathom of the hypothenuse; take out these numbers and multiply them respectively by the length of the hypothenuse.

EXAMPLE.

Given the angle 23° 30′, and hypothenuse 12 fathoms; the base and perpendicular are required.

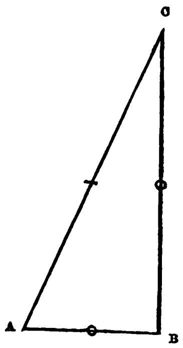
OPERATION.

Base.	Perpendicular.
Feet 2 . 4·70993	Feet 5 . 6·02833
12	12
28 . 8·51916	66 0·33996.

BY CONSTRUCTION.

Process.—Draw the line A B of any length, make the angle C=23° 30′ by a scale of chords, or with a protractor; draw the hypothenuse A C=72 feet from a scale of equal parts. From C let fall the perpendicular C B; then A B C is the triangle required. A B, measured by the same scale of equal parts, will be 28 feet 8½ inches. and B C will be 66 feet.

Scale.—40 feet to an inch.



CASE II.—WHEN THE PERPENDICULAR IS GIVEN.

Rule.—Look in the second table, and opposite the given angle will be found the base and hypothenuse corresponding to one fathom of the perpendicular; multiply these numbers separately by the length of the perpendicular.

EXAMPLE.

Given the angle 39° 30′, and perpendicular 9 fathoms 3 feet; the hypothenuse and base are required.

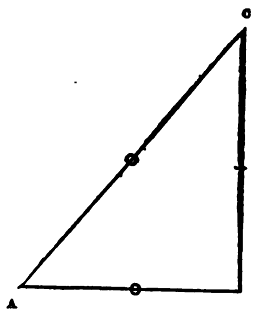
OPERATION.

			fath.	ft.	in.
3	½		0	4	11·3522
					9
			7	2	6·1698
			0	2	5·6761
		Base	7	4	11·8459*

			fath.	ft.	in.
3	½		1	1	9·3096
					9
			11	3	11·7864
			0	3	10·6548
		Hyp.	12	1	10·4412

BY CONSTRUCTION.

Process.—Draw the line A B of a sufficient length, at any point B erect the perpendicular B C, which make equal to 57 feet by a scale of equal parts. At C make the angle=39° 30′ the complement of A. From C draw the hypothenuse, and it will cut the base A B in the point A; then will A B measure 47 feet, and A C 73 feet 10 inches.



CASE III.—WHEN THE BASE IS GIVEN.

Rule.—Look in the third table, and opposite the given angle (as in the former cases) the corresponding numbers to one fathom of base will be seen, which being multiplied by the given length of the base, produces the hypothenuse and perpendicular.

EXAMPLE.

Given the angle 20 degrees and base 28 feet 9 inches; the hypothenuse and perpendicular are required.

		ft.	in.
∠20°	½	17	6·51392†
			4
		70	2·05568
	½	8	9·25696
	⅙	2	11·08565
		2	2·31424
Hyp.		84	0·71253

		ft.	in.
	½	16	5·81837†
			4
		65	11·27348
	½	8	2·90918
	⅙	2	8·96972
		2	0·72729
Perp.		78	11·87967

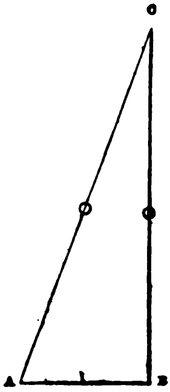
---

* It has been before observed that it would be better to bring the answer out in feet than in fathoms, as in the last case.

† These numbers stand in the tables in fathoms, &c., the hypothenuse will be found 2 fathoms, 5 feet, 6 inches, &c., and the perpendicular 2 fathoms, 4 feet, 5 inches, &c.

BY CONSTRUCTION.

Process.—Draw the base A B which make — 28 feet 9 inches, from a scale of equal parts, at B erect the perpendicular B C, make the angle A — 70° and draw the hypothenuse A C to cut the perpendicular B C in the point C, then will A C measure 84 feet, and B C 78 feet 11½ inches.



APPLICATION OF THE TABLES

TO

DIAGONAL SHAFTS.

REMARKS.

As in the foregoing cases each side of the triangle is distinctly made radius, it follows that every problem in oblique dialling, &c., can be solved by one or the other of these cases; because in every instance, a side and the angles are always given.

GENERAL RULE.

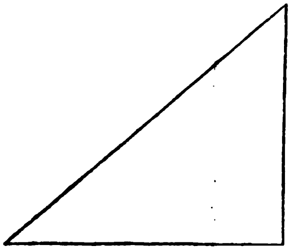
When the hypothenuse is given, work by case the first.
When the perpendicular is given, work by case the second.
When the base is given, work by case the third.

EXAMPLE I.

A diagonal shaft A B was found to measure 84 feet,* and the angle of declination observed to be 48 degrees; required the base B C, and perpendicular A C.

BY CASE I.

	ft.	in.
∠48°	4	5·50643
		7
	31	2·54501
		2
Base	62	5·09002
	ft.	in.
	4	0·17740
		7
	28	1.24180
		2
Perp.	56	2·48360



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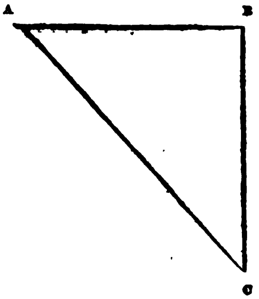
* When the given line is denominated in feet, it must be brought into fathoms by dividing it by 6, (the number of feet in a fathom;) thus, in the above example the shaft being 84 feet is 14 fathoms, and therefore the numbers are multiplied by 7 and 2, which are equal to 14.

EXAMPLE II.

A perpendicular shaft B C, measuring 57 feet, was found to intersect an underlaying shaft A C, whose angle of acclivity was observed to be 50° 30′; required the length of the underlaying shaft A C, and the distance from the perpendicular at the surface A B.

BY CASE II.

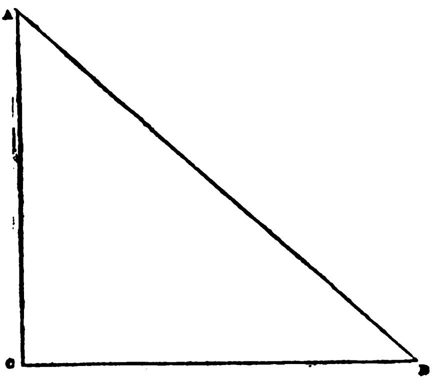
```
∠50° 30′ }                   ft.  in.
 Comp.   } Base | ¼ |         4  11·8522
 39° 30′ }                            9
                            ------------
                             44   6·1698
                              2   5·6761
                            ------------
                         A B 46  11·8459
                            ------------

                             ft.  in.
            Hyp. | ¼ |        7   9·3096
                                      9
                            ------------
                             69 11·7864
                              3 10·6548
                            ------------
                         A C 73 10·4412
                            ------------
```



NOTE.—In the above example the angle having again been taken with the horizon, the operative angle will be 89° 80′, because 90°—50° 30′—39° 30′. We may also observe that the length of the shaft being 57 feet, the multiplier is 9½, or 9 fathoms, 3 feet.

EXAMPLE III.

A horizontal cross-cut B C from the foot of a diagonal B A to a perpendicular shaft C A was found to measure 224 feet 8 inches, and the angle of acclivity (taken at B, the foot of the shaft) 40 degrees; I require the respective lengths of the hypothenuse A B and perpendicular A C.



BY CASE III.

		ft.	in.			ft.	in.
∠40° Comp. 50°	‡	7	9·98932*		‡	5	0·41517
			12				12
		93	11·87184			60	4·98204
			3				3
		281	11·61552			181	2·94612
		7	9·98932			5	0·41517
	‡	2	7·32977		‡	1	8·13839
		0	10·44325			0	6·71279
A	B	293	3·37786	A	C	188	6·21247

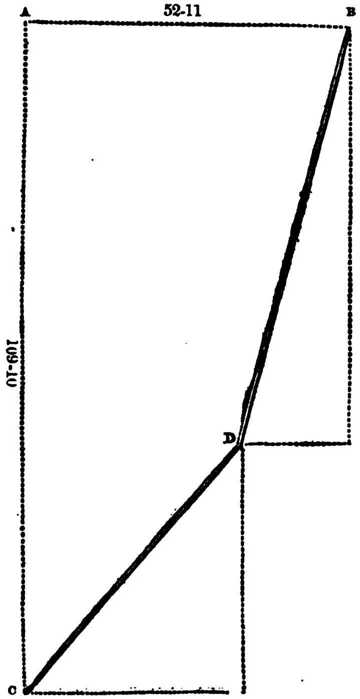
EXAMPLE IV.

When a lode has changed its underlay.

Rule.—Take out the numbers opposite the given angles, and work them by the former cases, then add their sums together respectively for the answer.

PROBLEM.

In dialling a shaft sunk on a lode, it was found that the first draft B D measured 71 feet, on an angle of 14° 45′, but from that depth to the foot of the shaft C the angle proved to be 40° 15′, and the length D C 54 feet; required the distance from the brace of the diagonal B, where a perpendicular shaft ought to be sunk, in order to come down exactly at the foot of the underlay; also the depth of the perpendicular A C.



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* It will be observed that this number stands in the table 1 fath. 1 ft. 9·98932 in., and the angle having been taken at the foot of the shaft, the complement of that angle (*i. e.* what it wants of 90°) must be used, therefore the above tabular numbers will be found in the column opposite 50°, being the complement of 40°.

OPERATION.

Base.

			fath.	ft.	in.
∠14° 45′	1	¼	0	1	6.33134
					12
			3	0	3.97608
			0	0	3.05522
			3	0	0·92086

Perpendicular.

		fath.	ft.	in.
1	¼	0	5	9.6273
				12
		11	3	7·5276
		0	0	11·6045
		11	2	7·9231

Base.

	fath.	ft.	in.
∠40° 15′—	0	3	10·52093
			9
	5	4	10.68837

Perpendicular.

fath.	ft.	in.
0	4	6·95274
		9
6	5	2·57466

Summary of Bases.

	fath.	ft.	in.
	3	0	0·92086
	5	4	10·68837
	8	4	11·60923
	6		
A B	52 feet 11 in.		

Summary of Perpendiculars.

	fath.	ft.	in.
	11	2	7·9231
	6	5	2·57466
	18	1	10·49776
	6		
A C	109 feet 10 in.		

EXAMPLE 5.

When a lode has changed or reversed its underlay from north to south, or east to west.

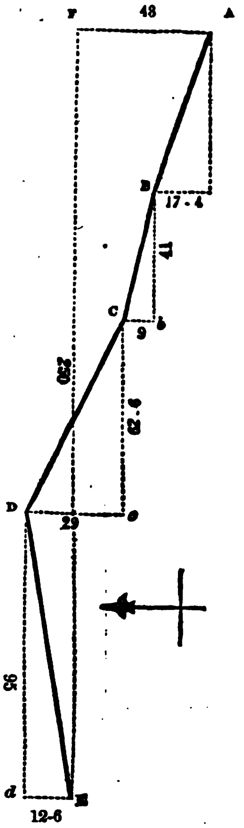
Rule.—Add all the perpendiculars together, as in the last problem, but subtract the bases, made by the reverse or contrary shafts, one from the other, the remainder will be the true length of the base.

PROBLEM.

A diagonal shaft was found to incline and measure as follows, viz.:

A B -	- 54 feet	18° 45′
B C -	- 42 do.	12° 15′
C D -	- 69 do.	25° 0′

throughout the above drafts, the declination or underlay bore northerly, but from that depth D it made an angle of 7° 30′ in a southerly direction, and this last draft D E measured 96 feet. It is required to know the perpendiculars and bases of all the foregoing sides respectively and collectively.



OPERATION.

Bases Northerly.	fath.	ft.	in.	Perpendiculars.	fath.	ft.	in.
∠18° 45′—	0	1	11·14364		0	5	8·17897
			9				9
B a	2	5	4·29276	A a	8	3	1·61073
∠12° 15′—	0	1	3·27680		0	5	10·36062
			7				7
C b	1	2	10·93760	B b	6	5	0·52434
∠25° 0′—	0	2	6·42852		0	5	5·25416
			11				11
	4	3	10·71872		9	5	9·79576
	0	1	3·21426		0	2	8·62708
D c	4	5	1·92798	C c	10	2	6·42284

Base Southerly.	fath.	ft.	in.		fath.	ft.	in.
∠7° 30′—	0	0	9·39789		0	5	11·38408
			8				8
	1	0	3·18312		7	5	7·07264
			2				2
E d	2	0	6,36624	D d	15	5	2·14448

SUMMARY.

Bases.	fath.	ft.	in.	Perpendiculars.	fath.	ft.	in.
	2	5	4·29276		8	8	1·61073
	1	2	10·93760		6	5	0·52434
	4	5	1·92798		10	2	6·42284
					15	5	2·14448
North	9	1	5·15834		41	3	10·70239
South	2	0	6·36624		6		
	7	0	10·79210	F E	249 ft.		10 in.
	6						
F A	42 ft.		10 in.				

EXAMPLE 6.

When a shaft has been sunk in error,* or not exactly at right angles with the lode.

Rule I.—Work for the base and perpendicular as before, by Case I., then find the deviation by the following.

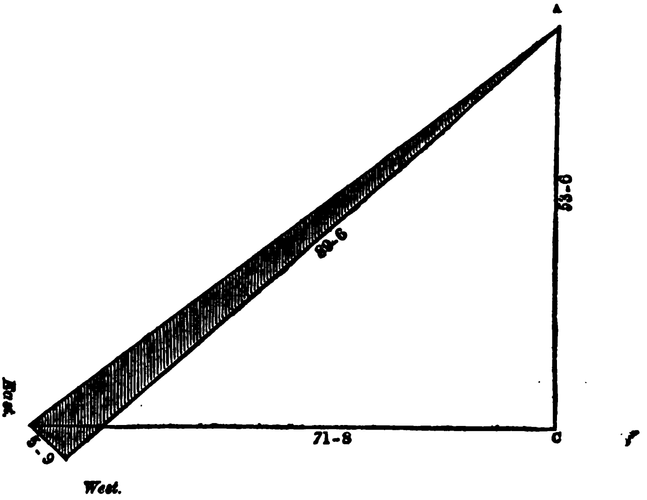
Rule II.—Take out the base from the second table, standing opposite the angle of error, and multiply it by the length of the shaft.

---

* Underlaying shafts are always intended to be sunk at right angles with the lode; that is, if the lode runs east and west, the horizontal bearing of the shaft will be either north or south, as the lode may happen to underlie. But it is sometimes the case, that through inattention of workmen or other causes, the shaft has declined from its true course and inclined toward the right or left, and as this is neither a trivial nor uncommon occurrence, and admits not of development by the ordinary mode of dialling, we have here introduced a rule which will hold good in all cases of the kind.

PROBLEM.

An oblique shaft A B was found to measure 89 feet 6 inches, on an angle of 53° 15′, and it was also observed that the shaft had declined 3° 45′ west from the intended right angle of the east and west lode: required the base C D and perpendicular C A, and how far the shaft has departed from its true course A D.



OPERATION.

			ft.	in.
∠53° 15′	3	½	4	9·69027
				7
			33	7·83189
				2
			67	3·66378
			2	4·84513
	2	⅓	1	7·23009
	0 6	¼	0	4·80752
		Base.	71	8.54652

		ft.	in.
3	½	3	7·07937
			7
		25	1·55559
			2
		50	3·11118
		1	9.53968
2	⅓	1	2·35979
0 6	¼	0	3·58994
	Perp.	53	6·60059

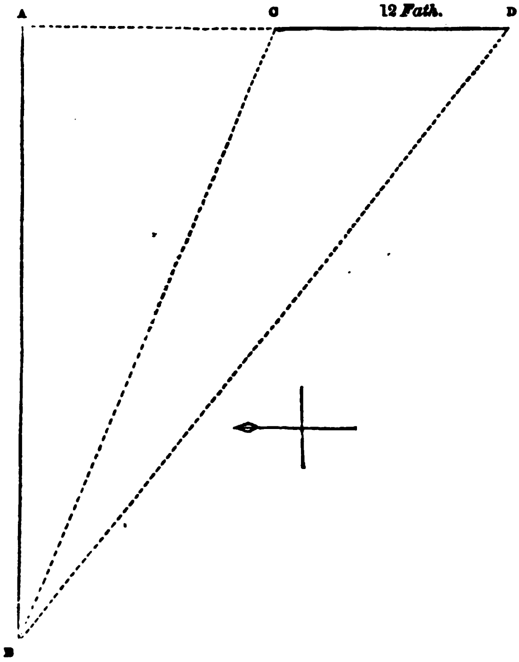
THEN FOR THE DEVIATION.

		ft.	in.
Table 2d.—∠3° 45′ Base	½	0	4.7189
			7
		2	9·0323
			2
		5	6·0646
		0	2·3594
	⅓	0	0·78
	¼	0	0·19
		5	9·3940

Thus it is clear that if the above shaft was sunk on an east and west lode and the angle of error inclined westerly, that the foot of the shaft B would be 5 feet, 9½ inches, in that direction beyond its designed course A D.

EXAMPLE 7.

To find the perpendicular depth of the junction of lodes.



CASE I.

When two lodes underlay in the same direction.

Rule.—Subtract the tabular number of the base of the lesser angle from the greater, then by direct proportion, say,

As this difference
Is to one fathom perpendicular,
So is the distance of the lodes at surface
To the junction of the lodes.

PROBLEM.

Two lodes were discovered at the surface, 12 fathoms apart from C to D, both underlaying north. The southernmost lode

D B made an angle of 38° 15′: the other C B 23°. Required the perpendicular depth A B where these lodes will unite, supposing they both regularly continue their respective angles of declination.

OPERATION.

```
                       ft.  in.
From ∠ 38° 15′—4   8·7602
Take ∠ 23°  0′—2   6·5622
                  ————————
                   2   2·1980
                  ————————

     ft.  in.         fath.      fath.
Then, As 2  2·198  :  1  : :     12
         12                       6
       ————————                  ——
       26·198                    72
                                 12
                             ————————
                   26·198) 864·000 (32·9
                           78594       6
                           ————      ———
                            78060     5·4
                            52396     12
                            ————      ———
                            256640    4·8
                            235782
                            ——————
                             20858
     fath. ft. in            ——————
Answer, 32   5  4 A B
```

DIAGONAL LODES.

If it is required to find the respective lengths of the lodes C B and D B, and the horizontal line D A, work by Case II., where the perpendicular is given.

TO FIND D B.

			fath.	ft.	in.
∠38° 15′	$\frac{1}{9}$		1	1	7·6831
					11
			14	0	0·5141
					3
			42	0	1·5423
			0	0	10·1870
		D B	41	5	3·3553

Here we multiply by 33, and subtract from the product what the hypothenuse is minus of that measure, which being eight inches, is one-ninth of a fathom. This is the shortest method.

TO FIND C B AND D A, OR C A.

			Base.					Hypothenuse.		
			fath.	ft.	in.			fath.	ft.	in.
∠23° 0′	$\frac{1}{9}$		0	2	6·5622	$\frac{1}{9}$		1	0	6·2179
					11					11
			4	4	0·1842			11	5	8·3969
					3					3
			14	0	0·5526			35	5	1·1907
			0	0	3·3964			0	0	8·6908
		C A	13	5	9·1580		C B	35	4	4·4999

Then C A + C D = D A, or C A added to C D gives the line D A, 25 fathoms, 5 feet, 9 inches, &c.

EXAMPLE 8.

To find the perpendicular depth of the junction of lodes.

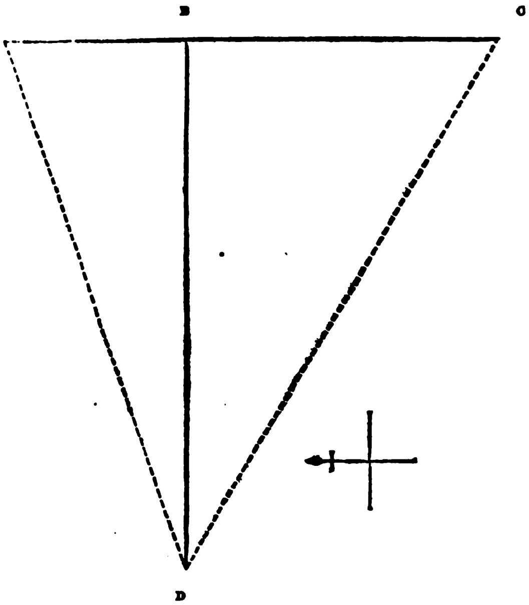
CASE II.

When two lodes, by their underlay, incline indirectly towards each other.

Rule.—Add the tabular bases together, then find the depth by direct proportion as in the last example.

PROBLEM.

Two lodes were observed 36 fathoms apart at the surface from A to C, the northernmost lode A underlaying south 18° 15′, and the southernmost lode C underlaying north 31° 45′: required the depth B D at which these lodes will intersect each other.



OPERATION.

```
         ft. in.                        ft. in.    fath.    fath.
To   ∠18° 15′ = 1 11·6220      Then, As 5  8·177  :  1  : :  36
Add  ∠31° 45′ = 3  8·5550               12                    6
               ----------               ---------           ----
                5  8·177                68·177               216
               ----------                                     12
                                                         ---------
                                             68·177) 2592·0000 (38·0
                                                     204531
                                                     ------
                                                      546690
                                                      545416
                                                      ------
                                                        12740
                                                      ------
                                        Answer 38 fathoms.
```

If required to find the length of the lodes A D and C D and the distance of the shaft B from the lodes C and A at the surface, work by case II. thus:

TO FIND A B AND A D.

	Base.				Hypothenuse.		
	fath.	ft.	in.		fath.	ft.	in.
∠18° 15′ =	0	1	11·622		1	0	3·8135
			6				6
	1	5	9·732		6	1	10·8810
			6				6
	11	4	10·392		37	5	5·2860
	0	3	11·244		2	0	7·6270
A B	12	2	9·636	A D	40	0	0·9130

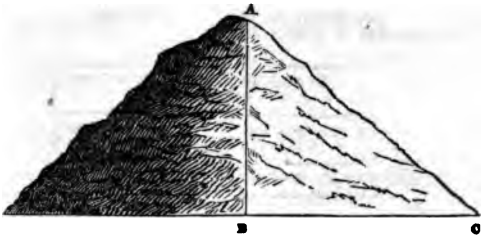
TO FIND B C AND C D.

	Base.				Hypothenuse.		
	fath.	ft.	in.		fath.	ft.	in.
∠31° 45′ =	0	3	8·555		1	1	0·7008
			6				6
	3	4	3·330		7	0	4·2048
			6				6
	22	1	7·980		42	2	1·2288
	1	1	8·110		2	2	1·4016
B C*	23	3	1·090	C D	44	4	2·6304

* It may be observed that A B and B C added together do not make 36 fathoms, by something more than an inch: now this does not happen through any defect in the tables, but because the perpendicular has not been worked out—for if the remainder (12740) was prosecuted, the perpendicular would prove to be 38 fath. 0 ft. 1·3892 in., instead of 38 fathoms, which addition to multipliers would make up the exact deficiency.

PERPENDICULAR SHAFTS AND LEVELS.

Rule.—When the angle of acclivity is given, take the complement (or what it wants of 90°) for the operative angle; in every other particular, work by the former cases.

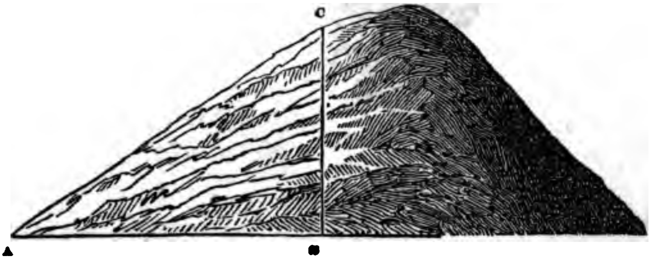


EXAMPLE I.

A perpendicular shaft having been sunk from the top of a hill at A, from whence the slope to C measured 330 feet: It is required to know the length an adit must be driven from the base of the hill at C to intersect the shaft at B, and what will be the depth of the shaft at that intersection, the angle of acclivity at C being 41 degrees.

BY CASE II.

	Perpendicular.		Base.	
	ft.	in.	ft.	in.
Comp. of 41° is 49°	3	11·23625	4	6·33909
		9		9
	35	5·12625	40	9·05181
		6		6
	212	6·75750	244	6·31086
	3	11·23625	4	6·33909
	216	5·99375	249	0·64995

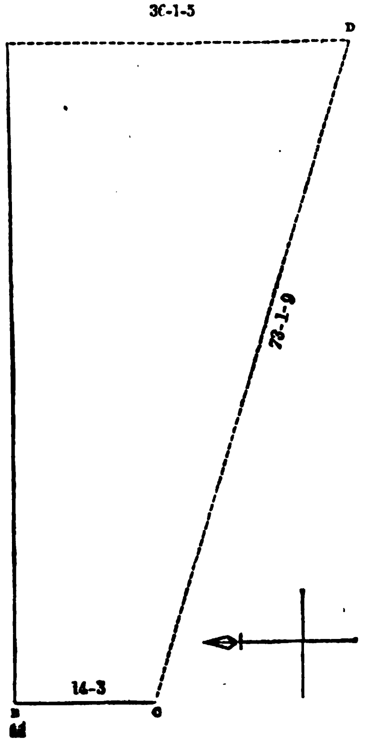


EXAMPLE II.

An adit having been driven 75 fathoms from A to B, required to know how far up the hill from A I ought to measure in order that a perpendicular may be sunk to intersect the adit at x, 58 fathoms from the tail at A; also the depth of the shaft C x, the angle of acclivity from A towards C being 33 degrees. Or thus:—Given the base 58 fathoms; angle of acclivity 33°, of which the complement or angle of declivity is 57°; required the hypothenuse and perpendicular.

BY CASE III.

	Hypothenuse.		Perpendicular.	
	ft.	in.	ft.	in.
Comp. ∠33° is 57° =	7	1·85016	3	10·75735
		8		8
	57	2·80128	31	2·05880
		7		7
	400	7·60896	218	2·41160
	14	3·70082	7	9·51470
A C	414	11·30928	C x 225	11·92630



EXAMPLE III.

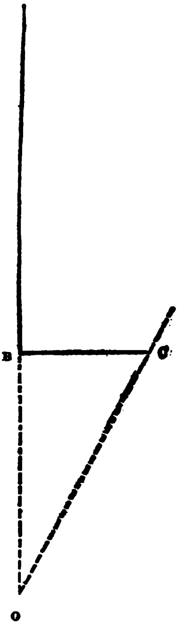
From the foot of a perpendicular shaft A B, 70 fathoms in depth, a cross-cut was driven south 14 fathoms 3 feet in length (C,) where a lode was discovered underlaying north, and the angle of ascension or elevation 72° 45′: required the length of this lode from the end of the drift C to the surface D; also the distance from the brace of the perpendicular shaft A to the back of the lode at grass (D,) supposing the lode to have a regular underlay.

BY CASE II.

	Base.			Hypothenuse.		
	fath.	ft.	in.	fath.	ft.	in.
Comp. of ∠72° 45' is 17° 15'	0	1	10·3560	1	0	3·3911
			7			7
	2	1	0·4920	7	1	11·7377
			10			10
	21	4	4·9200	73	1	9·3770
Add length of drift	14	3	0			
	36	1	4·92			

ANSWER.

	fath.	ft.	in.
Length of lode	73	1	9¼
Distance from shaft at the surface	36	1	5



EXAMPLE IV.

From the depth of 36 fathoms 4 feet, in an engine shaft A B, a cross-cut was driven which pierced a lode C, 14 fathoms, 2 feet, from B. The lode was found to make an angle of 30 degrees, inclining towards the shaft. Required the depth at which the shaft will intersect the lode, and the length of the lode from C to the point of intersection O.

BY CASE III.

	Hypothenuse.			Perpendicular.		
	fath.	ft.	in.	fath.	ft.	in.
∠30° ¼)	2	0	0	¼) 1	4	4·70766
			2			2
	4	0	0	3	2	9·41532
			7			7
	28	0	0	24	1	5·90724
	C	4	0	0	3	5·569
	28	4	0	24	4	11·47624

ANSWER.

	fath.	ft.	in.
Depth from A to B	36	4	0
Depth from B to o	24	4	11·47624
Extreme depth	61	2	11·47624

	fath.	ft
Length from C to o	28	4

SLIDES.

When a lode has been thrown up by a slide, to find the base and perpendicular.

Rule.—Add the bases made by the segments of the lode together for the horizontal, and subtract the perpendicular made by the ascension of the slide from the sum of the others for the perpendicular.

EXAMPLE.

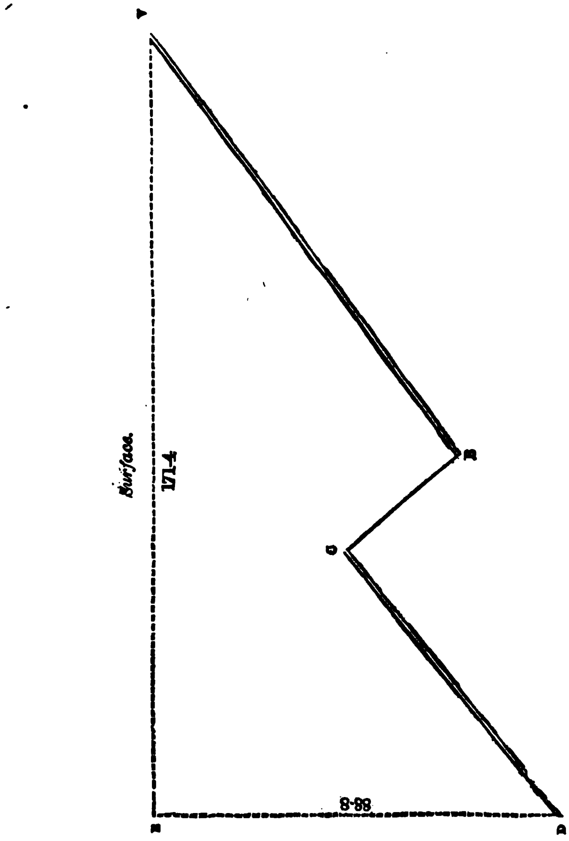
A shaft having been sunk on a lode 114 feet from A to B, on an angle of 54° 30′, at this place the lode was separated and thrown up by a slide, from B to C, 32 feet, the angle of elevation at B being 47°: at C the lode was again cut and prosecuted on an angle of 51°, from C to D, 73 feet. Required to know the length from A to E at surface, where a perpendicular shaft should be put down, that would intercept the lode at the foot of the diagonal C D; also the depth of the shaft E D.

THE FOREGOING EXAMPLE BY THE TABLES.

	Base.		Perpendicular.		
	ft.	in.	ft.	in.	
∠A 54° 30′=	4	10·61632	3	5·81062	
		6		6	
	29	3·69792	20	10·86372	(Multiplier
		3		3	19 fathoms.)
	87	11·09376	62	8·59116	
	4	10·61632	3	5·81062	
	92	9·71008	66	2·40178	

		Base.			Perpendicular.		
		ft.	in.		ft.	in.	
∠B 47° 0′ Comp. 43° 0′ }=	⅓	4	1·10388	⅓	4	4·65747	
			5			5	
		20	5·51940		21	11·28735	(Multiplier
		1	4·36796		1	5·552	5 fa. 2 ft.)
		21	9·88736		23	4·83935	

		ft.	in.		ft.	in.	
∠C 51° 0'	$\frac{1}{8}$	4	7·95451	$\frac{1}{8}$	3	9·31107	
			12			12	
		55	11·45412		45	3·73284	(Multiplier 12 fa. 1 ft.)
		0	9·32575		0	7·55184	
		56	8·77987		45	11·28468	



SUMMARY.

	Bases.	
	ft	in.
	92	9·71008
	21	9·88736
	56	8·77987
Answer E A =	171	4·87731

	Perpendiculars.	
	ft.	in.
∠A =	66	2·40178
∠C =	45	11·28468
	112	1·68646
∠B =	23	4·83935
D E =	88	8·84711

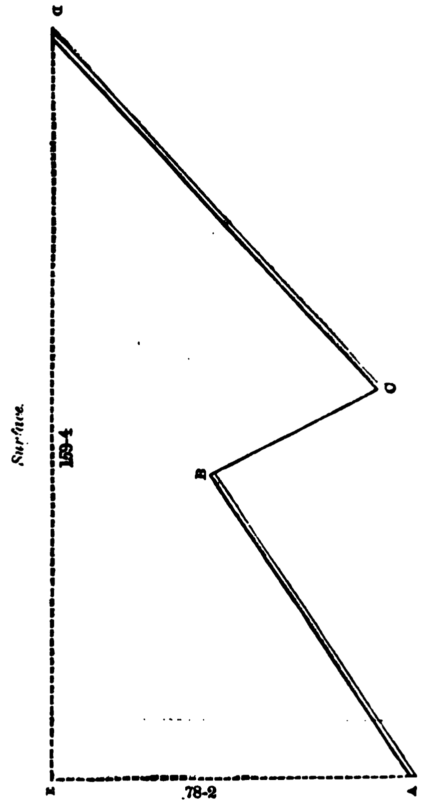
Note.—Perpendiculars to strike B or C and their respective horizontal distances from A are shown by the sums of the first and second operation in the above calculations.

When a lode has been thrown down by a slide.

Rule.—Add the perpendiculars together for the depth, and subtract the base of the slide from the bases of the segment of the lode for the horizontal.

EXAMPLE.

A shaft A B having been sunk 77 feet on a lode which made an angle of 34° 45′, it was there found that a slide had severed or disjoined the lode and carried it downward from B to C 40 feet, on an angle of depression or declivity 59°. Here (at C) the lode was again discovered, and wrought 102 feet from C to D, on an angle of 42° 15′; required the depth of the vertical line D E, and the length of the horizontal A E.



Note.—Should it be required to find the proper depth in the shaft D E from whence to drive a cross-cut to strike the end of the shaft A B, (where the slide first appeared,)—the perpendicular of the first draft gives the depth, and the length of the cross-cut will be found by subtracting the base of the first draft from the horizontal line A E: and should it be necessary to make a drift from the shaft D E to the angle C, (where the lode was again discovered,) the depth will be found by adding the perpendiculars of A and B together, and the bases of B and C will be the length of the drift.

THE FOREGOING EXAMPLE BY THE TABLES.

		Base.			Perpendicular.	
		ft.	in.		ft.	in.
∠A 34° 45′	½	3	5·03977	½	4	11·15858
			12			12
		41	0·47724		59	1·90296
		1	8·51988		2	5·57929
	⅓	1	1·67992	⅓	1	7·71952
		43	10·67704		63	3·20177

		ft.	in.		ft.	in.
∠B 59° 0′	½	5	1·71605	½	3	1·08274
			6			6
		30	10·29630		18	6·49644
	⅙	2	6·85802	⅙	1	6·54137
		0	10·28600		0	6·18045
		34	3·44032		20	7·21826

	Base.		Perpendicular.	
	ft.	in.	ft.	in.
∠C 42° 15′	4	0·41041	4	5·2957
		4		4
	16	1·64164	17	9·1828
		4		4
	64	6·56656	71	0·7312
	4	0·41041	4	5·2957
	68	6·97697	75	6·0269

SUMMARY.

	Bases.		Perpendiculars.	
	ft.	in.	ft.	in.
∠A . .	43	10·67704	63	3·20177
∠C . .	68	6·97697	20	7·21826
			75	6·0269
	112	5·65401		
∠B . .	34	3·44032		
Ans. A E =	78	2·21369	D E = 159	4·44693

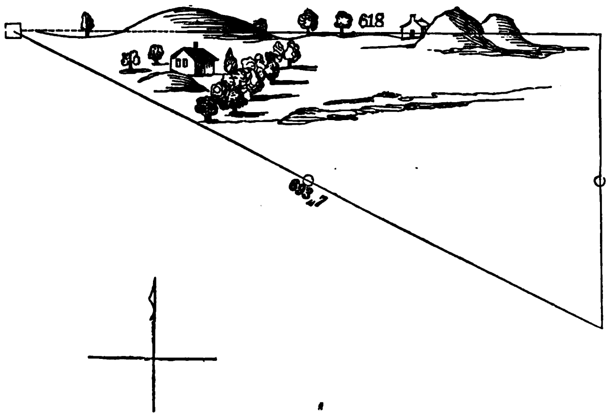
HORIZONTAL DIALLING.

Rule.—Observe which side of the triangle is given, and work by the specified case.

When there is more than one draft in the operation, add the sums of the respective sides together for the answer.

EXAMPLE I.

Being required to put down a shaft 618 feet due east of an engine shaft at A, I am prevented from measuring in a direct line by intervening hills and wood: I therefore find it necessary, in order to avoid these obstructions, to go on an angle of 27° south of east from the shaft A. What distance must I proceed in this direction before I come at right angles with, or due south of, the eastern extremity of the given line, and how far must I then measure in a northerly direction to come exactly on the re-



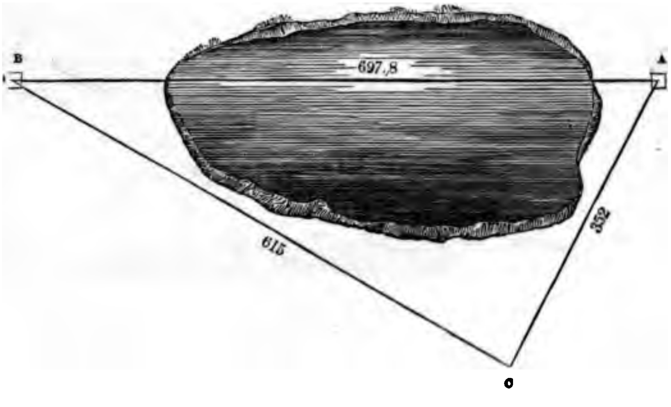
quired spot. Or the question may stand thus:—Given the perpendicular 618 feet, angle 27°; the hypothenuse and base are required.

OPERATION.

	Base.		Hypothenuse.	
	ft.	in.	ft.	in.
27° =	3	0·6858	6	8·8075
		10		10
	30	6·8580	67	4·0750
		10		10
(Multiplier 103 fath.)	305	8·5800	673	4·7500
	9	2·0574	20	2·4225
	314	10·6374	693	7·1725

EXAMPLE II.

It being required to find the distance between two shafts A and B, which are inaccessible to a direct measurement on account of a marsh or lake lying in the way: I consequently measure 352 feet on an angle of 63° south of west, from A to C; at this station (C) I can see the shaft B, which I find by observation bears 29° north of west, and the line from C to B measures 615 feet; how far are these shafts apart in a right line? Or the question may stand simply thus:—



{ Given angle 63°, hypothenuse 352 feet. }
{ Given angle 29°, hypothenuse 615 feet. }

The sum of the perpendiculars* are required.

---

* As in this instance the perpendicular only is wanted, there is no necessity for taking out the other side.

OPERATION. .

```
                 Perpendicular.                     Perpendicular.
                  ft.  in.                           ft.  in.
∠A 63° | ½ |      2   8·68782     ∠C 29° | ½ |       5   2·97262
       |   |             11              |   |              10
       |   |     ------------            |   |      ------------
       |   |     29 11·56052             |   |      52   5·72620
       |   |              5              |   |              10
       |   |     ------------            |   |      ------------
       |   |     149  9·80260            |   |      524  9·26200
       |   |       8  2·06196            |   |       10  5·94524
       |   |       1  4·34366            |   |        2  7·48631
       | ⅓ |       0  5·44788            |   |      ------------
             ------------                           537 10·69855
             159  9·65610                           ------------
             ------------

(Multiplier 58 fa. 4 ft.)                  (Multiplier 102 fa. 3 ft.)
```

SUM.

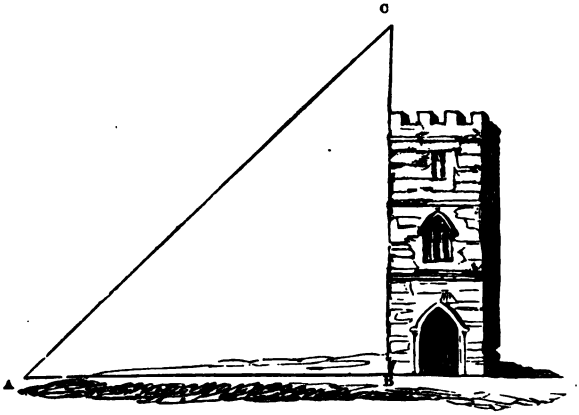
```
             ft.    in.
             159   9·65610
             537  10·69355
             -------------
Ans. A B.    697   8·34965
             -------------
```

VERTICAL DIALLING;

OR, THE

MENSURATION OF HEIGHTS.

Rule.—Observe the given side and angle, and work by the respective cases as heretofore.



EXAMPLE I.

From the bottom of a tower at B, I measured 200 feet in a direct line B A on an horizontal plane; I then took the angle A42°: required the height of the tower and staff B C.

OPERATION.

		ft.	in.
Complement of ∠A 42° is ∠C 48°	‡	5	4·82909
			11
		59	5·11999
			3
(Multiplier 53 fath. 2 ft.)		178	3·35997
		1	9·60969
Ans. B C		180	0·96966

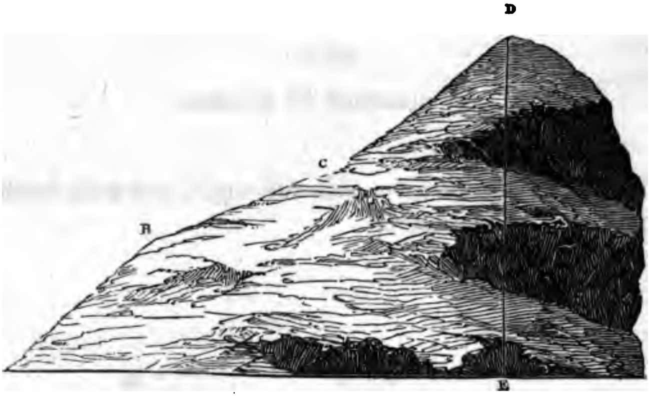
In operations of this nature the hypothenuse need not be regarded.

EXAMPLE II.

Wanting to ascertain the height of an irregular hill, I proceed, from the several stations A, B, and C, to take the angles and measure the distances as follows, viz.:

From A to B ∠41° 0′ length 210 feet.
From B to C ∠22° 0′ length 216 feet.
From C to D ∠37° 30′ length 247 feet.

required the altitude E D.



OPERATION.

		Perpendicular.	
		ft.	in.
∠A 41° 0′ Comp. 49° 0′		3	11·23625
6) 210			7
		27	6·65375
35 Multiplier			5
		137	9·26875
∠B 22° 0′ Comp. 68° 0′		2	2·97167
6) 216			6
36 Multiplier		13	5·83002
			6
		80	10·98012
∠C 37° 30′ Comp. 52° 30′	$\frac{1}{6}$	3	7·83082
			10
6) 247			
		36	6·30820
41 . 1 Multiplier			4
		146	1·23280
		3	7·83082
		0	7·30513
		150	4 36875

	ft.	in.
A	137	9·26875
B	80	10·98012
C	150	4·86875
Ans. height E D	369	0·61762

MISCELLANEOUS EXAMPLES IN THE FOREGOING RULES.

Given the hypothenuse 14 feet 5 inches, angle 88°: required the base and perpendicular.*

ft. in.
Answer { Base = 14 4·69
Perp. = 0 6·03

Given the perpendicular 100 feet, angle 60°: required the hypothenuse and base.

ft. in.
Answer { Hyp. = 200
Base = 173 2·428

Given the base 118 feet, angle (Comp.) 23°: required the hypothenuse and perpendicular.

ft. in.
Answer { Hyp. = 301 11·97
Perp. = 278 0·02

Given the angle 53°: required the underlay in a fathom.†

fath. ft. in.
Answer 1 1 11·5472

Given the angle 36° 45′: required the underlay in a fathom.

ft. in.
Answer 4 5·5650

Given the angle 4° 15′; required the underlay in a fathom.

in.
Answer 5·3496

A diagonal shaft having been sunk 8° 30′ out of its true course; what will be the extent of departure, supposing the length of the shaft 76 feet?

ft. in.
Answer 11 4·9577

[Suppose a diagonal shaft was sunk as follows, viz:

∠87° 0′ = 14 5
∠47 0 = 11 2
∠87 30 = 36 3
∠69 30 = 26 2
∠77 30 = 23 2
∠65 30 = 9 2

---

* In single drafts, one or two figures of the decimal will be sufficient, the others may be rejected.

† It has been before observed, that the underlay is given in the base of the second table.

Required the sum of the bases and perpendiculars.

Answer { Perp. 52 8·45944
Bases 169 6·90784

Wanting to know the distance between two shafts, inaccessible in a right line, I measured from the first shaft 126 feet, on an angle of 27° 15′ E. by N.; from this station to the second shaft the line measured 91 feet, on an angle of 42° 30′ N. by W.: how far are the shafts apart?

ft. in.
Answer 179 1·3

Wanting to know the altitude of a precipice, I measure off from its base 66 feet, and from thence I take the angle to the summit, which I find to be 42° (and consequently the complement 48°): required the height.

ft. in.
Answer 59 5·91999

At the foot of a hill the angle to the summit was 36°, from this place an adit had been driven in a direct line 218 feet: how far must I measure up the hill to put down a perpendicular shaft on the end of the adit, and what will be the depth of the shaft?

Answer { Hyp. or slope 281 5·54804
Perp. or shaft 158 4·62816

At the foot of a diagonal shaft, 28 fathoms in length, sunk on a lode 27° 45′ underlaying north, another lode was cut making an angle 48° 45′ underlaying south: what is the distance from the brace of the shaft to the back of the north lode?

FIRST TABLE.

	Base.		Perpendicular.		
	ft.	in.	ft.	in.	
∠27° 45′	2	9·5	5	3·7	
		7		7	
	19	6 5	37	1·9	
		4		4	
	78	2·0	148	7·6	Divide this by 6 for the multiplier of the 2d angle, which will be 24 fath. 4 ft. 7·6 in.

THEN—SECOND TABLE.

		Base.	
		ft.	in.
∠48° 45′ Comp. 41° 15′	⅛	5	3·14
			6
		31	6·84
			4
		126	3·36
	⅛	2	7·57
	½	0	10·52
	⅛	0	5.26
		0	0·65
		130	3·36

ANSWER.

	ft.	in.
Base of north lode	78	2
Base of south lode	130	3
Required distance	208	5

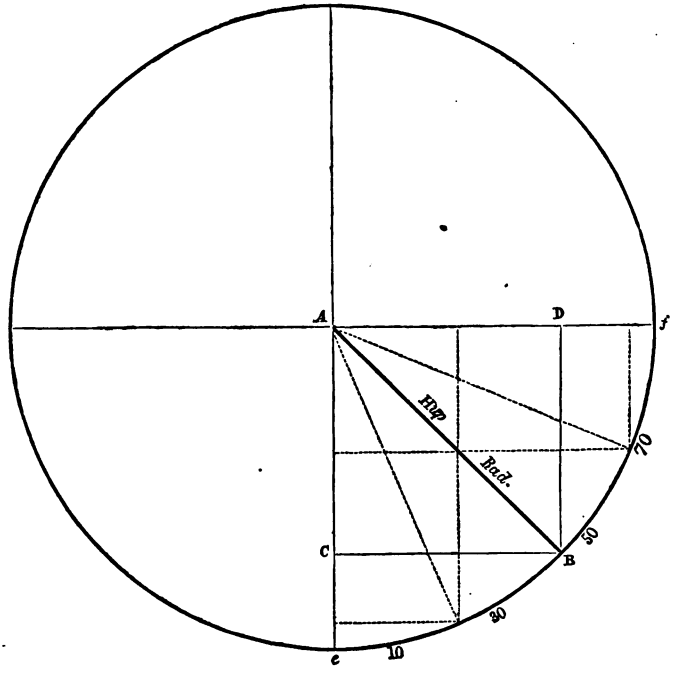
A perpendicular shaft having been sunk 168 feet in the side of a mountain, the slope or declivity making an angle with the shaft of 54° 15′ : required to know how far I must measure down the hill to get at the right spot for driving an adit to come in the exact depth of the shaft,—the length of the adit is also required.

		ft.	in.
Answer	Slope	287	8·58
	Adit	223	4·40

A lode underlaying south was observed to make an angle of 17° 15′: required to know what distance from the back of the lode will be proper for sinking a perpendicular shaft that shall intersect the lode at the depth of 45 fathoms.

	ft.	in.
Answer	83	10·020

HYPOTHENUSE RADIUS.



FIRST TABLE.

HYPOTHENUSE RADIUS, ONE FATHOM.

ANGLE.		BASE.			PERPENDICULAR.				
Deg.	Min.	Feet.	Ins.	Decimals	Feet.	Ins.	Decimals.	Deg.	Min.
1		0	1	·25657	5	11	·98903	89	
	15	0	1	·57067	5	11	·98286		45
	30	0	1	·88474	5	11	·97532		30
	45	0	2	·19877	5	11	·96664		15
2		0	2	·51276	5	11	·95614	88	
	15	0	2	·82666	5	11	·94249		45
	30	0	3	·14060	5	11	·93147		30
	45	0	3	·45442	5	11	·91708		15
3		0	3	·76819	5	11	·90132	87	
	15	0	4	·08188	5	11	·88420		45
	30	0	4	·39549	5	11	·86571		30
	45	0	4	·70902	5	11	·84584		15
4		0	5	·02246	5	11	·82461	86	
	15	0	5	·33581	5	11	·80201		45
	30	0	5	·64905	5	11	·77805		30
	45	0	5	·96219	5	11	·75272		15
5		0	6	·27521	5	11	·72602	85	
	15	0	6	·58811	5	11	·69793		45
	30	0	6	·90090	5	11	·66853		30
	45	0	7	·21354	5	11	·63773		15
6		0	7	·52605	5	11	·60558	84	
	15	0	7	·83842	5	11	·57205		45
	30	0	8	·15063	5	11	·53718		30
	45	0	8	·46269	5	11	·50093		15
7		0	8	·77459	5	11	·46333	83	
	15	0	9	·08633	5	11	·42435		45
	30	0	9	·39789	5	11	·38403		30
	45	0	9	·70926	5	11	·34234		15
8		0	10	·02046	5	11	·29930	82	
	15	0	10	·33147	5	11	·25490		45
	30	0	10	·64228	5	11	·20914		30
	45	0	10	·95288	5	11	·16203		15
9		0	11	·26328	5	11	·11356	81	
	15	0	11	·57347	5	11	·06374		45
	30	0	11	·88343	5	11	·01256		30
	45	1	0	· 316	5	10	·96004		15
10		1		·50267	5	10	·90616	80	
	15	1	0	·81193	5	10	·85093		45
	30	1	1	·12096	5	10	·79435		30
	45	1	1	·42973	5	10	·73643		15
11		1	1	·73825	5	10	·67716	79	
	15	1	2	·04650	5	10	·61654		45
	30	1	2	·35449	5	10	·55458		30
	45	1	2	·66221	5	10	·49128		15
12		1	2	·96964	5	10	·42663	78	
	15	1	3	·27680	5	10	·36062		45
PERPENDICULAR.					BASE.			ANGLE.	

ANGLE.		BASE.			PERPENDICULAR.				
Deg.	Min.	Feet.	Ins.	Decimals.	Feet.	Ins.	Decimals.	Deg.	Min.
12	30	1	3	·58365	5	10	·29331	78	30
	45	1	3	·89021	5	10	·22464		15
13		1	4	·19648	5	10	·15465	77	
	15	1	1	·50243	5	10	·08331		45
	30	1	4	·80807	5	10	·01062		30
	45	1	5	·11338	5	9	·93663		15
14		1	5	·41838	5	9	·86129	76	
	15	1	5	·72204	5	9	·72304		45
	30	1	6	·02736	5	9	·70663		30
	45	1	6	·33134	5	9	·62730		15
15		1	6	·63497	5	9	·54666	75	
	15	1	6	·93825	5	9	·46469		45
	30	1	7	·24116	5	9	·38139		30
	45	1	7	·54371	5	9	·29677		15
16		1	7	·84589	5	9	·21084	74	
	15	1	8	·14769	5	9	·12359		45
	30	1	8	·44910	5	9	·03502		30
	45	1	8	·75014	5	8	·94514		15
17		1	9	·05076	5	8	·85395	73	
	15	1	9	·35099	5	8	·76143		45
	30	1	9	·65082	5	8	·66762		30
	45	1	9	·95023	5	8	·57250		15
18		1	10	·24922	5	8	·47607	72	
	15	1	10	·54779	5	8	·37833		45
	30	1	10	·84594	5	8	·27931		30
	45	1	11	·14364	5	8	·17897		15
19		1	11	·44091	5	8	·07734	71	
	15	1	11	·73772	5	7	·97441		45
	30	2	0	·03409	5	7	·87019		30
	45	2	0	·33000	5	7	·76467		15
20		2	0	·62545	5	7	·65787	70	
	15	2	0	·92043	5	7	·54977		45
	30	2	1	·21493	5	7	·44040		30
	45	2	1	·50895	5	7	·32973		15
21		2	1	·80249	5	7	·21779	69	
	15	2	2	·09554	5	7	·10457		45
	30	2	2	·38809	5	6	·99007		30
	45	2	2	·68013	5	6	·87429		15
22		2	2	·97167	5	6	·75724	68	
	15	2	3	·26270	5	6	·63892		45
	30	2	3	·55320	5	6	·51932		30
	45	2	3	·84320	5	6	·39847		15
23		2	4	·13264	5	6	·27635	67	
	15	2	4	·42156	5	6	·15297		45
	30	2	4	·70993	5	6	·02833		30
	45	2	4	·99776	5	5	·90243		15
24		2	5	·28503	5	5	·77528	66	
	15	2	5	·57176	5	5	·64686		45
	30	2	5	·85791	5	5	·51721		30
	45	2	6	·14350	5	5	·38631		15
25		2	6	·42852	5	5	·25416	65	
	15	2	6	·71295	5	5	·12077		45
PERPENDICULAR.					BASE.			ANGLE.	

ANGLE.		BASE.			PERPENDICULAR.				
Deg.	Min.	Feet.	Ins.	Decimals.	Feet.	Ins.	Decimals.	Deg.	Min.
25	30	2	6	·99680	5	4	·98614	65	30
	45	2	7	·28106	5	4	·85027		15
26		2	7	·56272	5	4	·71317	64	
	15	2	7	·84479	5	4	·57483		45
	30	2	8	·12622	5	4	·43528		30
	45	2	8	·40708	5	4	·29448		15
27		2	8	·68732	5	4	·15247	63	
	15	2	8	·96692	5	4	·00923		45
	30	2	9	·24590	5	3	·86478		30
	45	2	9	·52424	5	3	·71911		15
28		2	9	·80195	5	3	·57223	62	
	15	2	10	·07902	5	3	·42413		45
	30	2	10	·35543	5	3	·27483		30
	45	2	10	·63120	5	3	·12433		15
29		2	10	·90630	5	2	·97262	61	
	15	2	11	·18073	5	2	·81972		45
	30	2	11	·45450	5	2	·66561		30
	45	2	11	·72759	5	2	·51031		15
30		3	0	·00000	5	2	·35383	60	
	15	3	0	·27173	5	2	·19616		45
	30	3	0	·54276	5	2	.03730		30
	45	3	0	·81310	5	1	.87726		15
31		3	1	·08274	5	1	.71605	59	
	15	3	1	·35168	5	1	.55366		45
	30	3	1	·61990	5	1	.39009		30
	45	3	1	·88740	5	1	.22536		15
32		3	2	·15419	5	1	.05946	58	
	15	3	2	·42024	5	0	.89240		45
	30	3	2	·68557	5	0	.72418		30
	45	3	2	·95016	5	0	.55481		15
33		3	3	·21401	5	0	.38428	57	
	15	3	3	·47711	5	0	.21261		45
	30	3	3	·73946	5	0	.03978		30
	45	3	4	·00105	4	11	.86581		15
34		3	4	·26189	4	11	.69071	56	
	15	3	4	·52195	4	11	.51446		45
	30	3	4	·78125	4	11	.33709		30
	45	3	5	·03977	4	11	.15858		15
35		3	5	·29750	4	10	.97894	55	
	15	3	5	·55445	4	10	.79819		55
	30	3	5	·81062	4	10	.61632		30
	45	3	6	·06598	4	10	.43333		15
36		3	6	·32054	4	10	.24922	54	
	15	3	6	·57429	4	10	.06401		45
	30	3	6	·82724	4	9	.87770		30
	45	3	7	·07937	4	9	.69027		15
37		3	7	·33068	4	9	.50176	53	
	15	3	7	·58117	4	9	.31214		45
	30	3	7	·83082	4	9	.12144		30
	45	3	8	·07965	4	8	.92965		15
38		3	8	·32763	4	8	.73678	52	
	15	3	8	·57476	4	8	.54282		45
PERPENDICULAR.					BASE.			ANGLE.	

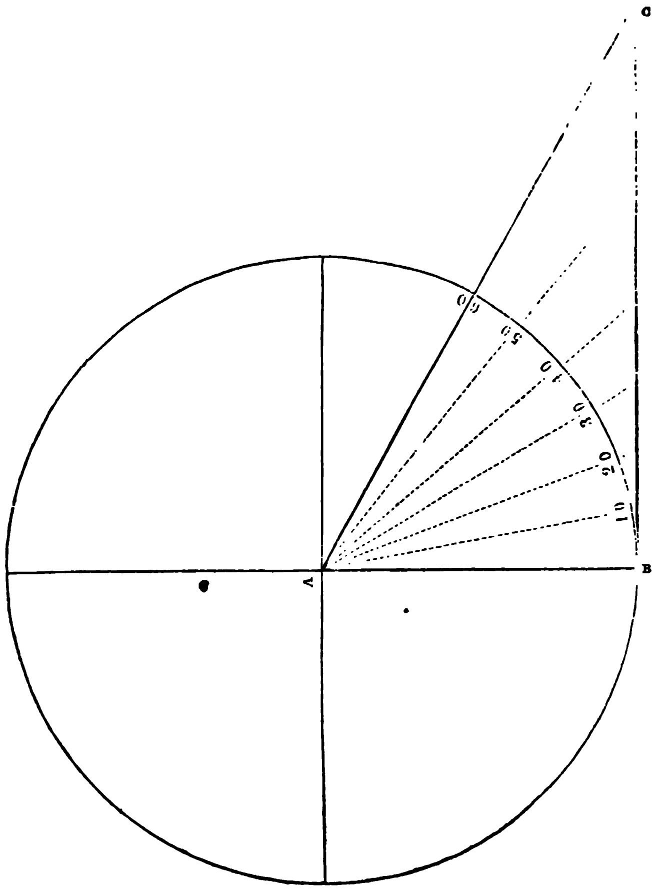
ANGLE.		BASE.			PERPENDICULAR.				
Deg.	Min.	Feet.	Ins.	Decimals.	Feet.	Ins.	Decimals.	Deg.	Min.
38	30	3	8	·82105	4	8	·34779	52	30
	45	3	9	·06649	4	8	·15168		15
39		3	9	·31107	4	7	·95451	51	
	15	3	9	·55478	4	7	·75627		45
	30	3	9	·79763	4	7	·55697		30
	45	3	10	·03961	4	7	·35661		15
40		3	10	·28071	4	7	·15520	50	
	15	3	10	·52093	4	6	·95274		45
	30	3	10	·76026	4	6	·74923		30
	45	3	10	·99871	4	6	·54468		15
41		3	11	·23625	4	6	·33909	49	
	15	3	11	·47290	4	6	·13246		45
	30	3	11	·70864	4	5	·92481		30
	45	3	11	·94348	4	5	·71613		15
42		4	0	·17740	4	5	·50643	48	
	15	4	0	·41041	4	5	·29570		45
	30	4	0	·64250	4	5	·08396		30
	45	4	0	·87365	4	4	·87122		15
43		4	1	·10388	4	4	·65747	47	
	15	4	1	·33318	4	4	·44271		45
	30	4	1	·56153	4	4	·22696		30
	45	4	1	·78894	4	4	·01021		15
44		4	2	·01540	4	3	·79247	46	
	15	4	2	·24092	4	3	·57374		45
	30	4	2	·46547	4	3	·35403		30
	45	4	2	·68906	4	3	·13335		15
45		4	2	·91169	4	2	·91169	45	
PERPENDICULAR.					BASE.			ANGLE.	

Note.—The following table had no place in the former edition, but will be found useful in particular cases for long lines where the angle is required to be very minute. It will be seen that as there is but the thousandth part of an inch difference in one fathom between the hypothenuse and perpendicular on the first 15′ or first ¼ of a degree, the introduction of the decimal at any less fraction would be useless.

ANGLE.		BASE.			PERPENDICULAR.				
Deg.	Min.	Feet.	Ins.	Decimals.	Feet.	Ins.	Decimals.	Deg.	Min.
	1	0	0	·02094	6	0		89	59
	2	0	0	·04189	6	0		89	58
	3	0	0	·06283	6	0		89	57
	4	0	0	·08387	6	0		89	56
	5	0	0	·10482	6	0		89	55
	6	0	0	·12576	6	0		89	54
	7	0	0	·14670	6	0		89	53
	8	0	0	·16765	6	0		89	52
	9	0	0	·18859	6	0		89	51
	10	0	0	·20943	6	0		89	50
	11	0	0	·23038	6	0		89	49
	12	0	0	·25132	6	0		89	48
	13	0	0	·27225	6	0		89	47
	14	0	0	·29319	6	0		89	46
	15	0	0	·31414	5	11	·99932	89	45
	30	0	0	·62831	5	11	·99726	89	30
	45	0	0	·94245	5	11	·99381	89	15
PERPENDICULAR.					BASE.			ANGLE.	

SECOND TABLE.

PERPENDICULAR RADIUS, ONE FATHOM.



ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
1		0	0	1	·2568	1	0	0	·0108
	15	0	0	1	·5710	1	0	0	·0171
	30	0	0	1	·8854	1	0	0	·0247
	45	0	0	2	·1998	1	0	0	·0335
2		0	0	2	·5143	1	0	0	·0432
	15	0	0	2	·8289	1	0	0	·0554
	30	0	0	3	·1435	1	0	0	·0684
	45	0	0	3	·4582	1	0	0	·0828
3		0	0	3	·7728	1	0	0	·0986
	15	0	0	4	·0882	1	0	0	·1159
	30	0	0	4	·4035	1	0	0	·1346
	45	0	0	4	·7189	1	0	0	·1544
4		0	0	5	·0328	1	0	0	·1757
	15	0	0	5	·3496	1	0	0	·1980
	30	0	0	5	·6664	1	0	0	·2171
	45	0	0	5	·9825	1	0	0	·2484
5		0	0	6	·2993	1	0	0	·2736
	15	0	0	6	·6168	1	0	0	·3024
	30	0	0	6	·9336	1	0	0	·3312
	45	0	0	7	·2497	1	0	0	·3636
6		0	0	7	·5672	1	0	0	·3960
	15	0	0	7	·8841	1	0	0	·4298
	30	0	0	8	·2008	1	0	0	·4658
	45	0	0	8	·5212	1	0	0	·5026
7		0	0	8	·8402	1	0	0	·5400
	15	0	0	9	·1584	1	0	0	·5803
	30	0	0	9	·4788	1	0	0	·6192
	45	0	0	9	·7992	1	0	0	·6624
8		0	0	10	·1189	1	0	0	·7056
	15	0	0	10	·4393	1	0	0	·7531
	30	0	0	10	·7604	1	0	0	·7992
	45	0	0	11	·0808	1	0	0	·8474
9		0	0	11	·4034	1	0	0	·8971
	15	0	0	11	·7259	1	0	0	·9482
	30	0	1	0	·0485	1	0	1	·0008
	45	0	1	0	·3696	1	0	1	·0548
10		0	1	0	·6936	1	0	1	·1088
	15	0	1	1	·0176	1	0	1	·1664
	30	0	1	1	·3416	1	0	1	·2262
	45	0	1	1	·6692	1	0	1	·2859
11		0	1	1	·9954	1	0	1	·3476
	15	0	1	2	·3215	1	0	1	·4106
	30	0	1	2	·6484	1	0	1	·4750
	45	0	1	2	·9760	1	0	1	·5410
12		0	1	3	·3036	1	0	1	·6085
	15	0	1	3	·6326	1	0	1	·6775
	30	0	1	3	·9617	1	0	1	·7481
	45	0	1	4	·2914	1	0	1	·8202
13		0	1	4	·6219	1	0	1	·8939
	15	0	1	4	·9538	1	0	1	·9691
	30	0	1	5	·2857	1	0	2	·0459
	45	0	1	5	·6178	1	0	2	·1242
14		0	1	5	·9496	1	0	2	·2042
	15	0	1	6	·2858	1	0	2	·2857

ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
14	30	0	1	6	·6192	1	0	2	·3688
	45	0	1	6	·9576	1	0	2	·4535
15		0	1	7	·2888	1	0	2	·5399
	15	0	1	7	·6294	1	0	2	·6338
	30	0	1	7	·9670	1	0	2	·7174
	45	0	1	8	·3062	1	0	2	·8087
16		0	1	8	·6456	1	0	2	·9015
	15	0	1	8	·9858	1	0	2	·9961
	30	0	1	9	·3271	1	0	3	·0443
	45	0	1	9	·6695	1	0	3	·1902
17		0	1	10	·0126	1	0	3	·2898
	15	0	1	10	·3560	1	0	3	·3911
	30	0	1	10	·7003	1	0	3	·4941
	45	0	1	11	·0472	1	0	3	·5988
18		0	1	11	·3942	1	0	3	·7053
	15	0	1	11	·6220	1	0	3	·8135
	30	0	2	0	·0905	1	0	3	·9234
	45	0	2	0	·4204	1	0	4	·0352
19		0	2	0	·7916	1	0	4	·1487
	15	0	2	1	·1435	1	0	4	·2640
	30	0	2	1	·4965	1	0	4	·3811
	45	0	2	1	·8506	1	0	4	·5000
20		0	2	2	·2058	1	0	4	·6208
	15	0	2	2	·5622	1	0	4	·7434
	30	0	2	2	·9197	1	0	4	·8679
	45	0	2	3	·2783	1	0	4	·9942
21		0	2	3	·6262	1	0	5	·1224
	15	0	2	3	·9993	1	0	5	·2526
	30	0	2	4	·3615	1	0	5	·3846
	45	0	2	4	·7251	1	0	5	·5186
22		0	2	5	·0899	1	0	5	·6545
	15	0	2	5	·4560	1	0	5	·7924
	30	0	2	5	·8234	1	0	5	·9323
	45	0	2	6	·1921	1	0	6	·0741
23		0	2	6	·5622	1	0	6	·2179
	15	0	2	6	·9336	1	0	6	·3638
	30	0	2	7	·3065	1	0	6	·5117
	45	0	2	7	·6807	1	0	6	·6617
24		0	2	8	·0565	1	0	6	·8138
	15	0	2	8	·4336	1	0	6	·9679
	30	0	2	8	·8123	1	0	7	·1242
	45	0	2	9	·1924	1	0	7	·2826
25		0	2	9	·5741	1	0	7	·4432
	15	0	2	9	·9574	1	0	7	·6059
	30	0	2	10	·3422	1	0	7	·7708
	45	0	2	10	·7287	1	0	7	·9380
26		0	2	11	·1167	1	0	8	·1073
	15	0	2	11	·5065	1	0	8	·2789
	30	0	2	11	·8979	1	0	8	·4528
	45	0	3	0	·2910	1	0	8	·6290
27		0	3	0	·6858	1	0	8	·8075
	15	0	3	1	·0824	1	0	8	·9883
	30	0	3	1	·4808	1	0	9	·1714
	45	0	3	1	·8810	1	0	9	·3571

ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
1		0	0	1	·2568	1	0	0	·0108
	15	0	0	1	·5710	1	0	0	·0171
	30	0	0	1	·8854	1	0	0	·0247
	45	0	0	2	·1998	1	0	0	·0335
2		0	0	2	·5143	1	0	0	·0432
	15	0	0	2	·8289	1	0	0	·0554
	30	0	0	3	·1435	1	0	0	·0684
	45	0	0	3	·4582	1	0	0	·0828
3		0	0	3	·7728	1	0	0	·0986
	15	0	0	4	·0882	1	0	0	·1159
	30	0	0	4	·4035	1	0	0	·1346
	45	0	0	4	·7189	1	0	0	·1544
4		0	0	5	·0328	1	0	0	·1757
	15	0	0	5	·3496	1	0	0	·1980
	30	0	0	5	·6664	1	0	0	·2171
	45	0	0	5	·9825	1	0	0	·2484
5		0	0	6	·2993	1	0	0	·2736
	15	0	0	6	·6168	1	0	0	·3024
	30	0	0	6	·9336	1	0	0	·3312
	45	0	0	7	·2497	1	0	0	·3636
6		0	0	7	·5672	1	0	0	·3960
	15	0	0	7	·8841	1	0	0	·4298
	30	0	0	8	·2008	1	0	0	·4658
	45	0	0	8	·5212	1	0	0	·5026
7		0	0	8	·8402	1	0	0	·5400
	15	0	0	9	·1584	1	0	0	·5803
	30	0	0	9	·4788	1	0	0	·6192
	45	0	0	9	·7992	1	0	0	·6624
8		0	0	10	·1189	1	0	0	·7056
	15	0	0	10	·4393	1	0	0	·7531
	30	0	0	10	·7604	1	0	0	·7992
	45	0	0	11	·0808	1	0	0	·8474
9		0	0	11	·4034	1	0	0	·8971
	15	0	0	11	·7259	1	0	0	·9482
	30	0	1	0	·0485	1	0	1	·0008
	45	0	1	0	·3696	1	0	1	·0548
10		0	1	0	·6936	1	0	1	·1088
	15	0	1	1	·0176	1	0	1	·1664
	30	0	1	1	·3416	1	0	1	·2262
	45	0	1	1	·6692	1	0	1	·2859
11		0	1	1	·9954	1	0	1	·3476
	15	0	1	2	·3215	1	0	1	·4106
	30	0	1	2	·6484	1	0	1	·4750
	45	0	1	2	·9760	1	0	1	·5410
12		0	1	3	·3036	1	0	1	·6085
	15	0	1	3	·6326	1	0	1	·6775
	30	0	1	3	·9617	1	0	1	·7481
	45	0	1	4	·2914	1	0	1	·8202
13		0	1	4	·6219	1	0	1	·8939
	15	0	1	4	·9538	1	0	1	·9691
	30	0	1	5	·2857	1	0	2	·0459
	45	0	1	5	·6178	1	0	2	·1242
14		0	1	5	·9496	1	0	2	·2042
	15	0	1	6	·2858	1	0	2	·2857

ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
14	30	0	1	6	·6192	1	0	2	·3688
	45	0	1	6	·9576	1	0	2	·4535
15		0	1	7	·2888	1	0	2	·5399
	15	0	1	7	·6294	1	0	2	·6338
	30	0	1	7	·9670	1	0	2	·7174
	45	0	1	8	·3062	1	0	2	·8087
16		0	1	8	·6456	1	0	2	·9015
	15	0	1	8	·9858	1	0	2	·9961
	30	0	1	9	·3271	1	0	3	·0443
	45	0	1	9	·6695	1	0	3	·1902
17		0	1	10	·0126	1	0	3	·2898
	15	0	1	10	·3560	1	0	3	·3911
	30	0	1	10	·7003	1	0	3	·4941
	45	0	1	11	·0472	1	0	3	·5988
18		0	1	11	·3942	1	0	3	·7053
	15	0	1	11	·6220	1	0	3	·8135
	30	0	2	0	·0905	1	0	3	·9234
	45	0	2	0	·4204	1	0	4	·0352
19		0	2	0	·7916	1	0	4	·1487
	15	0	2	1	·1435	1	0	4	·2640
	30	0	2	1	·4965	1	0	4	·3811
	45	0	2	1	·8506	1	0	4	·5000
20		0	2	2	·2058	1	0	4	·6208
	15	0	2	2	·5622	1	0	4	·7434
	30	0	2	2	·9197	1	0	4	·8679
	45	0	2	3	·2783	1	0	4	·9942
21		0	2	3	·6262	1	0	5	·1224
	15	0	2	3	·9993	1	0	5	·2526
	30	0	2	4	·3615	1	0	5	·3846
	45	0	2	4	·7251	1	0	5	·5186
22		0	2	5	·0899	1	0	5	·6545
	15	0	2	5	·4560	1	0	5	·7924
	30	0	2	5	·8234	1	0	5	·9323
	45	0	2	6	·1921	1	0	6	·0741
23		0	2	6	·5622	1	0	6	·2179
	15	0	2	6	·9336	1	0	6	·3638
	30	0	2	7	·3065	1	0	6	·5117
	45	0	2	7	·6807	1	0	6	·6617
24		0	2	8	·0565	1	0	6	·8138
	15	0	2	8	·4336	1	0	6	·9679
	30	0	2	8	·8123	1	0	7	·1242
	45	0	2	9	·1924	1	0	7	·2826
25		0	2	9	·5741	1	0	7	·4432
	15	0	2	9	·9574	1	0	7	·6059
	30	0	2	10	·3422	1	0	7	·7708
	45	0	2	10	·7287	1	0	7	·9380
26		0	2	11	·1167	1	0	8	·1073
	15	0	2	11	·5065	1	0	8	·2789
	30	0	2	11	·8979	1	0	8	·4528
	45	0	3	0	·2910	1	0	8	·6290
27		0	3	0	·6858	1	0	8	·8075
	15	0	3	1	·0824	1	0	8	·9883
	30	0	3	1	·4808	1	0	9	·1714
	45	0	3	1	·8810	1	0	9	·3571

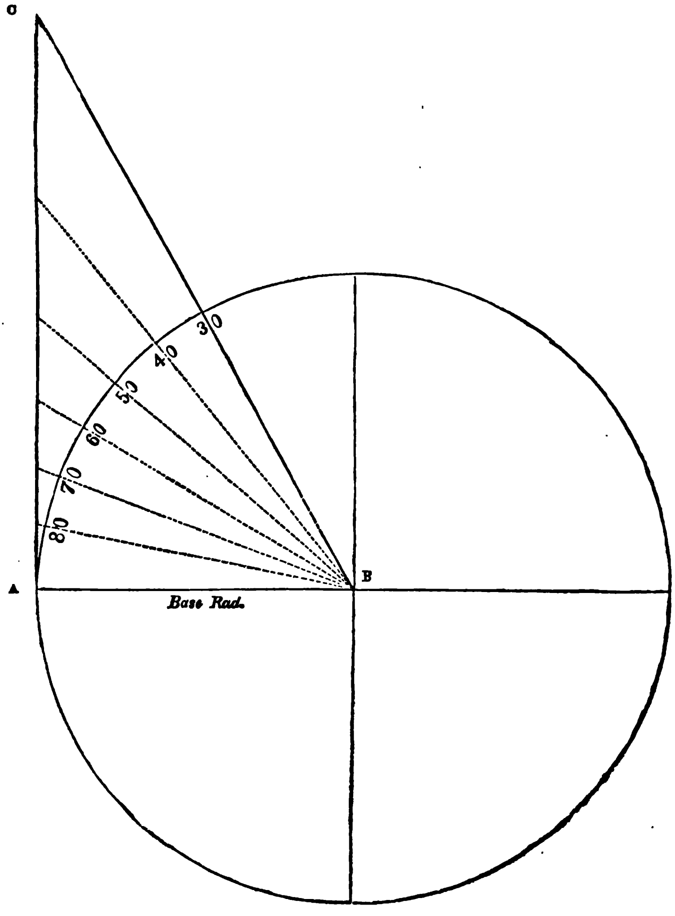
ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
28		0	3	2	·2831	1	0	9	·5450
	15	0	3	2	·6870	1	0	9	·7354
	30	0	3	3	·0928	1	0	9	·9283
	45	0	3	3	·5005	1	0	10	·1232
29		0	3	3	·9102	1	0	10	·3212
	15	0	3	4	·3219	1	0	10	·5220
	30	0	3	4	·7356	1	0	10	·7251
	45	0	3	5	·1514	1	0	10	·9303
30		0	3	5	·5692	1	0	11	·1384
	15	0	3	5	.9892	1	0	11	·3494
	30	0	3	6	·4112	1	0	11	·5625
	45	0	3	6	·8355	1	0	11	·7788
31		0	3	7	·2620	1	0	11	·9976
	15	0	3	7	·6907	1	1	0	·2192
	30	0	3	8	·1216	1	1	0	·4436
	45	0	3	8	·5550	1	1	0	·7008
32		0	3	8	·9906	1	1	0	.9008
	15	0	3	9	·4286	1	1	1	·1338
	30	0	3	9	·8691	1	1	1	·3696
	45	0	3	10	·3119	1	1	1	·6084
33		0	3	10	·7573	1	1	1	·8501
	15	0	3	11	·2053	1	1	2	·0949
	30	0	3	11	·6558	1	1	2	·3427
	45	0	4	0	·1088	1	1	2	·5937
34		0	4	0	·5646	1	1	2	·8477
	15	0	4	0	·9931	1	1	3	·1049
	30	0	4	1	·4842	1	1	3	·3653
	45	0	4	1	·9482	1	1	3	·6289
35		0	4	2	·4149	1	1	3	·8958
	15	0	4	2	·8846	1	1	4	·1660
	30	0	4	3	·3571	1	1	4	·4395
	45	0	4	3	·8326	1	1	4	·7165
36		0	4	4	·3111	1	1	4	·9969
	15	0	4	4	·7914	1	1	5	·2808
	30	0	4	5	·2772	1	1	5	·6819
	45	0	4	5	·5650	1	1	5	·8591
37		0	4	6	·2559	1	1	6	·1538
	15	0	4	6	·7501	1	1	6	·4520
	30	0	4	7	·2475	1	1	6	·7540
	45	0	4	7	·7483	1	1	7	·0597
38		0	4	8	·2526	1	1	7	·3693
	15	0	4	8	·7602	1	1	7	·6831
	30	0	4	9	·2834	1	1	8	·0000
	45	0	4	9	·7861	1	1	8	·3214
39		0	4	10	·3044	1	1	8	·6467
	15	0	4	10	·8265	1	1	8	·9761
	30	0	4	11	·3522	1	1	9	·3096
	45	0	4	11	·8818	1	1	9	·6473
40		0	5	0	·4152	1	1	9	·9893
	15	0	5	0	·9525	1	1	10	·0956
	30	0	5	1	·4938	1	1	10	·6863
	45	0	5	2	·0392	1	1	11	·0413
41		0	5	2	·5886	1	1	11	·4009
	15	0	5	3	.1420	1	1	11	·7651

ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
41	30	0	5	3	·7002	1	2	0	·1338
	45	0	5	4	·2624	1	2	0	·5049
42		0	5	4	·8291	1	2	0	·8855
	15	0	5	5	·4002	1	2	1	·2686
	30	0	5	5	·9758	1	2	1	·6566
	45	0	5	6	·5705	1	2	2	·0496
43		0	5	7	·1411	1	2	2	·4476
	15	0	5	7	·7308	1	2	2	·8507
	30	0	5	8	·3254	1	2	3	·2591
	45	0	5	8	·9250	1	2	3	·6727
44		0	5	9	·5296	1	2	4	·0918
	15	0	5	10	·1393	1	2	4	·5163
	30	0	5	10	·7542	1	2	4	·9463
	45	0	5	11	·3744	1	2	5	·3820
45		1	0	0	·0000	1	2	5	·8234
	15	1	0	0	·6311	1	2	6	·2706
	30	1	0	1	·2677	1	2	6	·7237
	45	1	0	1	·9101	1	2	7	·1828
46		1	0	2	·5852	1	2	7	·6481
	15	1	0	3	·2122	1	2	8	·1195
	30	1	0	3	·8722	1	2	8	·5973
	45	1	0	4	·5382	1	2	9	·0814
47		1	0	5	·2105	1	2	9	·5721
	15	1	0	5	·8892	1	2	10	·0694
	30	1	0	6	·5742	1	2	10	·5735
	45	1	0	7	·2658	1	2	11	·0844
48		1	0	7	·9641	1	2	11	·6023
	15	1	0	8	·6692	1	3	0	·1273
	30	1	0	9	·3812	1	3	0	·6596
	45	1	0	10	·1003	1	3	1	·1991
49		1	0	10	·8265	1	3	1	·7462
	15	1	0	11	·5601	1	3	2	·3009
	30	1	1	0	·3012	1	3	2	·8634
	45	1	1	1	·0498	1	3	3	·4337
50		1	1	1	·8062	1	3	4	·0122
	15	1	1	2	·5699	1	3	4	·5987
	30	1	1	3	·3430	1	3	5	·1936
	45	1	1	4	·1236	1	3	5	·7970
51		1	1	4	·9126	1	3	6	·4091
	15	1	1	5	·7101	1	3	7	·0300
	30	1	1	6	·5164	1	3	7	·6599
	45	1	1	7	·3316	1	3	8	·2990
52		1	1	8	·1560	1	3	8	·9474
	15	1	1	8	·9893	1	3	9	·6053
	30	1	1	9	·8322	1	3	10	·2729
	45	1	1	10	·6848	1	3	10	·9505
53		1	1	11	·5472	1	3	11	·6381
	15	1	2	0	·4197	1	4	0	·3360
	30	1	2	1	·3024	1	4	1	·0445
	45	1	2	2	·1956	1	4	1	·7636
54		1	2	3	·0995	1	4	2	·4937
	15	1	2	4	·0143	1	4	3	·2350
	30	1	2	4	·9403	1	4	3	·9876
	45	1	2	5	·8776	1	4	4	·7520

ANGLE.		BASE.				HYPOTHENUSE.			
Deg.	Min.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
55		1	2	6	·8267	1	4	5	·5282
	15	1	2	7	·7876	1	4	6	·3165
	30	1	2	8	·7606	1	4	7	·1172
	45	1	2	9	·7458	1	4	7	·9306
56		1	2	10	·7444	1	4	8	·7570
	15	1	2	11	·7556	1	4	9	·6966
	30	1	3	0	·7801	1	4	10	·4497
	45	1	3	1	·8182	1	4	11	·3165
57		1	3	2	·8703	1	5	0	·1976
	15	1	3	3	·9365	1	5	1	·0932
	30	1	3	5	·0174	1	5	2	·0034
	45	1	3	6	·1131	1	5	2	·9287
58		1	3	7	·2241	1	5	3	·8697
	15	1	3	8	·3507	1	5	4	·8265
	30	1	3	9	·4933	1	5	5	·7994
	45	1	3	10	·6523	1	5	6	·7890
59		1	3	11	·7281	1	5	7	·7955
	15	1	4	1	·0211	1	5	8	·8194
	30	1	4	2	·2317	1	5	9	·8612
	45	1	4	3	·4604	1	5	10	·9212
60		1	4	4	·7077	2	0	0	·0000

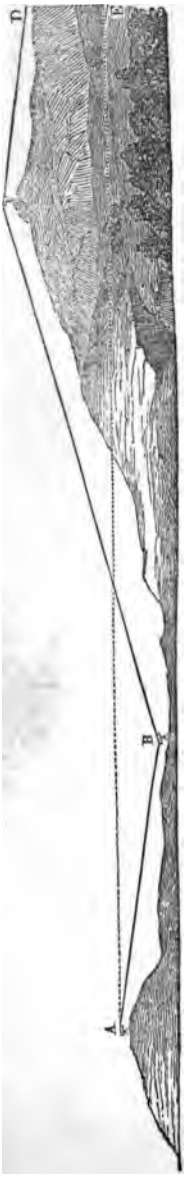
THIRD TABLE.

BASE RADIUS, ONE FATHOM.



ANGLE.	HYPOTHENUSE.				PERPENDICULAR.			
Deg.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
1	57	1	9	·50554	57	1	8	·87726
2	28	3	11	·06698	28	3	9	·81022
3	19	0	7	·72726	19	0	5	·84186
4	14	2	0	·16226	14	1	9	·64795
5	11	2	10	·10734	11	2	6	·96374
6	9	3	4	·80760	9	3	1	·03424
7	8	1	2	·79665	8	0	10	·39294
8	7	1	1	·34135	7	0	8	·30662
9	6	2	4	·25663	6	1	10	·59011
10	5	4	6	·63148	5	4	0	·33229
11	5	1	5	·34070	5	0	10	·40789
12	4	4	10	·30087	4	4	2	·73337
13	4	2	8	·06963	4	1	11	·86626
14	4	0	9	·61672	4	0	0	·77622
15	3	5	2	·18664	3	4	4	·70766
16	3	3	9	·21278	3	2	11	·09384
17	3	2	6	·26186	3	1	7	·50139
18	3	1	4	·99690	3	0	5	·59321
19	3	0	5	·15185	2	5	5	·10318
20	2	5	6	·51392	2	4	5	·81837
21	2	4	8	·91082	2	3	7	·56641
22	2	4	0	·20164	2	2	10	·20626
23	2	3	4	·26994	2	2	1	·62137
24	2	2	9	·01872	2	1	5	·71465
25	2	2	2	·36651	2	0	10	·40450
26	2	1	8	·24438	2	0	3	·62187
27	2	1	2	·59363	1	5	9	·30796
28	2	0	9	·36392	1	5	3	·41231
29	2	0	4	·51190	1	4	9	·89144
30	2	0	0	·00000	1	4	4	·70766
31	1	5	7	·79549	1	3	11	·82812
32	1	5	3	·86975	1	3	7	·22408
33	1	5	0	·19765	1	3	2	·87028
34	1	4	8	·75699	1	2	10	·74439
35	1	4	5	·52817	1	2	6	·82666
36	1	4	2	·49371	1	2	3	·09950
37	1	3	11	·63809	1	1	11	·54722
38	1	3	8	·94738	1	1	8	·15579
39	1	3	6	·40913	1	1	4	·91260
40	1	3	4	·01211	1	1	1	·80626
41	1	3	1	·74622	1	0	10	·82652
42	1	2	11	·60231	1	0	7	·96410
43	1	2	9	·57201	1	0	5	·21055
44	1	2	7	·64807	1	0	2	·55818
45	1	2	5	·82338	1	0	0	·00000
46	1	2	4	·09178	0	5	9	·52959
47	1	2	2	·44758	0	5	7	·14108
48	1	2	0	·88555	0	5	4	·82909
49	1	1	11	·40094	0	5	2	·58864
50	1	1	9	·98932	0	5	0	·41517
51	1	1	8	·64669	0	4	10	·30445
52	1	1	7	·36931	0	4	8	·25256
53	1	1	6	·15377	0	4	6	·25589
54	1	1	4	·99689	0	4	4	·31106

ANGLE.	HYPOTHENUSE.				PERPENDICULAR.			
Deg.	Fath.	Feet.	Ins.	Decimals.	Fath.	Feet.	Ins.	Decimals.
55	1	1	3	·89577	0	4	2	·41494
56	1	1	2	·84768	0	4	0	·56461
57	1	1	1	·85016	0	3	10	·75735
58	1	1	0	·90084	0	3	8	·99060
59	1	0	11	·99760	0	3	7	·26196
60	1	0	11	·13844	0	3	5	·56922



LEVELLING.

Rule.—Add all the perpendiculars together for the base line or horizontal distance, and subtract the bases made by the angles of elevation and depression one from the other, for the perpendicular or difference of height.*

EXAMPLE.

Being required to level an irregular piece of ground, I measured in a S. W. direction 64 yards from A to B, on an angle of depression 9° 45′; from this station I measured 120 yards from B to C, in the same cardinal direction, on an angle of elevation 16° 30′; and from thence to the extent of the ground the line on the same course measured 44 yards from C to D, and the angle of depression 7°; required the base line or horizontal distance from the place where the levelling was begun, to the point where it was ended; also how much higher or lower the ground is at the place where the operation terminated, than where it commenced.

Perpendiculars.

	ft.	in		fath.		ft.	in.
∠ 90° 45′ =	5	10·96004	×	32	=	189	2·72128
∠ 16° 30′ =	5	9·03502	×	60	=	345	2 10120
∠ 7° 0′ =	5	11·46333	×	22	=	131	0·19326
					3)	665	5·01574
					A E	221 yds.	2 ft. 5 in.

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* The altitudes of irregular hills are generally ascertained by the assistance of a spirit level and perpen-

Bases.

Elevation. Depression.

	ft.	in		fath.	ft.	in
∠9° 45′ =	1	0.19316	×	32 =	32	6·18112
∠7° 0′ =	0	8·77459	×	22 =	18	1·04098
					50	7·22210
∠16° 80′ =	1	8·44910	×	60 =	102	2·94600
				3)	51	7·72390
				E D	17 yds. 0 ft.	7½ in.

ANSWER.

	yds.	ft.	in.
Horizontal distance A E	221	2	5
Elevation E D . . .	17	0	7½

dicular poles, and if the ground rise and descend alternately, the differences between the heights of the poles are added when ascending, and subtracted when descending, in order to determine the different elevations and depressions of the ground: the foregoing rule and method will be found far more correct and masterly, remembering always that the height of the instrument be accounted for, which may easily be done by taking the observation from a staff or target the same height as the instrument.

HORIZONTAL, OR TRAVERSE DIALLING.

Plane sailing in navigation, and horizontal dialling in mining, are nothing more than the practice of right angled trigonometry, calling the hypothenuse the distance, the perpendicular the difference of latitude, the base the departure, and the angle opposite the base the course: consequently any range of dialling, however complicated and extensive, may be reduced into a single triangle, the perpendicular of which will either be the east and west, or north and south line, according to the main direction or bearing of the work; the hypothenuse will be the actual length of the dialling in a right line from the point of setting out to the termination; the base will be the distance the terminating point will fall right or left of the perpendicular; and the angle made by the hypothenuse with the perpendicular, will be the final course or direction of the work.

The variation of the compass is an evident and important cause of discrepancies occurring in mine surveys made at different dates, particularly when, as is too often the case, the old diallers omitted to show the then actual variations on their compass points. To determine at any time the variation of the compass involves the necessity of determining a meridian line, an operation of some difficulty, which may, I think, be dispensed with by the following method:—In making a true survey of a mine, let the dialler, with the same instrument he uses underground, run a north and south line on the surface, in any convenient part of the sett, marking the extremities by well-fixed points, such as iron pins let into stone. These points, being marked on the plan, will form a datum north and south line, with which at any time a dialler can compare his instruments, and make the necessary allowance for change of variation. If at any time either of the points should become liable to be covered with deads or other works, it would only be necessary to run a parallel line in a less obstructed locality, and mark the same on the plan. In adding fresh dialling to an old plan on which no variation is marked, select two points most likely to have been carefully laid down, such as the centres of two shafts, &c.; then, by comparing their bearing as laid down with the bearing actually taken on the ground, the dialler would determine the amount of variation between the date of the plan and the date of his own work, and could, therefore, lay down and put on the plan a datum north and south line. In dialling an underground level, if there be reason to suppose that the needle is affected by any local attraction, it would be sufficient, supposing such local attraction to be continuous, to dial the reverse way, taking the same stations, and the mean of each two observations. If the local attraction, however, is not continuous, but merely exists at certain points, the only correction possible would be repeating the observations, and changing each time the position of the instrument.

When a point (such as the position of a proposed shaft, &c.) has been fixed underground, and it is required to determine the same on the surface, the common plan with most captains is to repeat the observations; in fact, to make on the surface a copy of their underground dialling. Now, this is objectionable, inasmuch as in repeating a multiplicity of angles there is always danger of error, and the surface, being often rugged or hilly, is not adapted to the instrument commonly used. It would, of course, be easy to determine trigonometrically the point required by one observation, by reducing the angles taken, exactly as a log-book at sea might be reduced; but I think that by laying down the underground work on a good scale on paper the same result might be obtained, in a manner much simpler and more easily understood by those unaccustomed to mathematical calculations. As few dials are read to less than half a degree, a comman brass protractor, such as is found in cheap drawing instrument cases, would ensure all necessary accuracy; this, and a box-wood scale, any intelligent miner would soon acquire the use of, and a very little knowledge of drawing would enable him to construct a cardboard protractor of any size he might deem convenient. The method of plotting, instead of calculating reduced dialling is, I am convinced from practice, not only simpler, but more expeditious, less liable to error, and much more easily checked than effecting the same trigonometrically. At the same time, should any prefer the latter method, the natural sines and cosines for degrees and half degrees from 0 to 45, which could be easily written on a small card, are all that is required.

It therefore follows, that the general practice of repeating or retracing a course of underground dialling on the surface may be avoided, and thereby the difficulties and dangers arising from obstructions, irregular ground, and the attraction of the magnet by iron, which always abounds in the vicinity of a mine, be done away.

What is said of Mercator's sailing may, in the chief respect, be applied to horizontal dialling, viz.: "It is the art of finding on a plane surface the motion of a ship upon any assigned course by the compass, which shall be true in latitude, longitude, and distance sailed;" and certainly this includes the whole theory and practice of navigation; and if any method could be devised for measuring a ship's course and distance truly, nothing would be wanting:—also in dialling, it is only required to find a method for reducing the various windings and angles of a level or adit into a right line, and discovering the real extent and direction of that line, to complete the art.

But not to occupy the reader's time in telling him what he well knows already, we shall proceed to introduce the process for obtaining the length and bearing of a course of traverse dialling by the trigonometrical tables.

The first thing to be attended to is the statement of the work, or so placing the drafts that there may be no confusion in the operation, and that the perpendiculars and bases may fall on their proper sides.

In order to succeed in this essential matter, which may be considered the foundation of the work, note on which cardinal point the main direction of your dialling runs, whether east, west, north, or south, and reckon off your degrees right or left from that line: thus—if your dialling runs easterly or westerly, let the equator, or east and west line, be the point for numbering off your angles—if northerly or southerly, the meridian or north and south line; consequently this line will be the perpendicular of every triangle in the operation that comes within the sweep of half the circle, or 180°; and should any of the drafts return beyond the north or south points, or exceed 90° right or left of the east point, then the angle must be counted from the west toward the north or south, as the draft may happen to incline.

This being done, it is evident that on a course of east and west dialling, the bases north and bases south must be subtracted one from the other, and the remainder will be the departure or base line, north or south as the dialling may have prevailed on this or that side, and if any of the drafts have gone westerly, then the perpendiculars west must be subtracted from the perpendiculars east, for the real length of the perpendicular; but if the dialling has prevailed most in a westerly direction, the perpendicular will lie on that side: in short, as a matter of course, either for the difference of latitude, or rather difference of longitude in this case (the perpendicular), or for the departure (the base), the lesser number must be taken from the greater, and the differences will show the sides on which the operation lies.

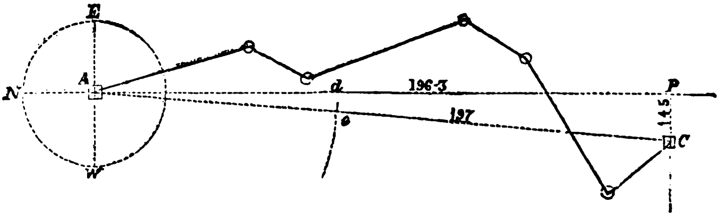
This process must all be performed by the first table, where the hypothenuse is given, because in every case the actual measured line will be the longest side of the triangle, and after stating the work, as before directed, take out the numbers standing against the given angles in the table and multiply them respectively by the length of the hypothenuse, reduced into fathoms and parts (if any), and place them in their proper positions until the whole has been calculated; then take the sum of the bases north and south one from the other, and the sum of the perpendiculars east and west one from the other, the perpendicular remainders will show the east and west line, and the bases the distance the dialling has extended north or south of that line.

The work is now brought to that case where the difference of latitude and departure are given to find the course and distance, and in order to avoid the necessity of introducing extensive and intricate tables, used by navigators for this purpose, we shall have recourse to one simple act of instrumental operation, and as two sides of the triangle are given, the thing may be quickly and safely performed; thus—draw the base the given length by a scale of equal parts, raise the perpendicular on one end of the base (and of course at right angles therewith), and mark off the given length, draw the hypothenuse, and the triangle will be complete: then, by the same scale, measure the hypothenuse, and it will be the actual length of the dialling in a right line, from beginning to end; then, with a protractor or scale of chords, measure the angle opposite the departure or base, and it will be the true course, bearing, or direction of the extreme points.

The degrees on the miner's compass are generally graduated from 1 to 360, and are figured toward the left hand, consequently 90° stands at the west point, 180° at south, 270° at the east, and ends with 360° at the north; and when the same course is to be pursued, that is, when the angles are to be taken and the drafts measured again, there will be no necessity for finding the real direction of the line, for as the sights are always fixed, the dialler need only be careful to observe that the needle stands at the same degree as in the original course; but when the operation is to be plotted or trigonometrically proved, there will be a necessity for ascertaining the actual bearing of every draft in the work, and this may be done by the following rule.

RULE.—SIGHTS FIXED NORTH AND SOUTH.

When the needle rests on any degree	*The direction of the sights or course of the dialling will be*
From 1 to 90 N. to W.	E. of N. Comp. N. of E.
From 90 to 180 W. to S.	S. of E. Comp. E. of S.
From 180 to 270 S. to E.	W. of S. Comp. S. of W.
From 270 to 360° E. to N.	N. of W. Comp. W. of N.



EXAMPLE I.

It is required to sink a perpendicular shaft on the end of a level whose angles and drafts are measured as follows, viz.:

					ft.	in.		fa.	ft.	in.
∠16°	30′	E.	of	S.	53	6	or	8	5	6
∠26°	0′	W.	of	S.	22	11	or	3	4	11
∠19°	0′	E.	of	S.	58	0	or	9	4	0
∠84°	30′	W.	of	S.	21	6	or	3	3	6
∠57°	30′	W.	of	S.	53	8	or	8	5	8
∠39°	30′	E.	of	S.	29	10	or	4	5	10

What distance is the end C (in the annexed plate), where the dialling was finished, from the engine shaft A where the dialling was begun, and what is the bearing of the line A C, or how many degrees are contained in the angle B A C?

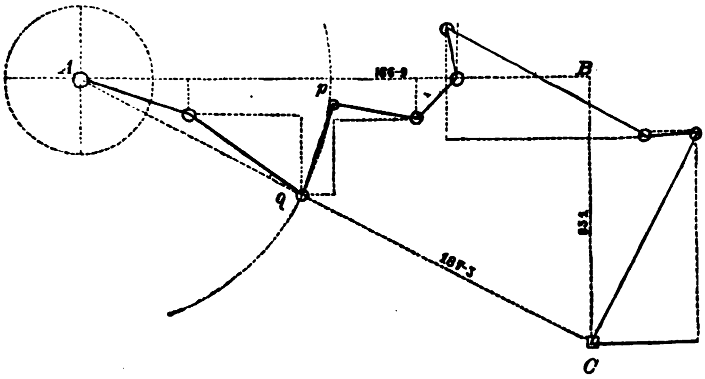
OPERATION.

Bases.

	ft.	in.	fath.	ft.	in.	ft.	in.
E. of S. 16°½ =	1	8·44910	× 8	5	6 =	15	2·33790
W. of S. 26° =	2	7·56272	× 3	4	11 =	10	0·53916
E. of S. 19° =	1	11·44091	× 9	4	0 =	18	10·58864
W. of S. 34°½ =	3	4·78125	× 3	3	6 =	12	2·13235
W. of S. 57°½ =	5	0·72418	× 8	5	8 =	45	3·18762
E. of S. 39°½ =	3	9·79763	× 4	5	10 =	18	11·55815

	ft.	in.
Sum of bases W. of S.	67	5.85913
Sum of bases E. of S.	53	0·48469
Base or departure Westerly B C =	14	5·37444

Scale 40 feet to an inch.



Perpendiculars.

deg.	ft.	in.	fath.	ft.	in.	ft.	in.
∠16½ =	5	9·03502	× 8	5	6 =	51	8·56228
∠26 =	5	4·71317	× 3	4	11 =	20	7·16851
∠19 =	5	8·07734	× 9	4	0 =	54	10·06606
∠34½ =	4	11·33709	× 3	3	6 =	17	8·69417
∠57½ =	3	2·68557	× 8	5	8 =	28	10·05018
∠39½ =	4	7·55697	× 4	5	10 =	23	0·04485
Perpendicular or diff. of latitude, A B						196	3·51605

THEN—BY CONSTRUCTION.

Draw two lines at right angles, as A B and B C, and of an indefinite length, take 196 feet, 3½ inches, in your compasses from a scale of equal parts, and with one foot in the right angle B, point off the distance B A for the perpendicular. Again take 14 feet, 5½ inches from the same scale, and apply it to the other line B C for the base; draw the hypothenuse to join A C, which by the same scale will be found to measure 197 feet.

FOR THE ANGLE.

With the chord of 60° in your compasses and centre A, describe an arc *e d* cutting A B and A C in *d* and *e*; then take the distance *e d* in your compasses, and setting one foot on the brass pin at the beginning of the chords on your scale, observe how many degrees the other foot reaches to, which will be 4° 15′ for the arc *e d* or angle B A C.

ANSWER.

197 feet, on an angle of 4° 15′ west of south.

EXAMPLE II.

Given the following course of traverse dialling, viz.:

Degrees at which the needle stood on the outer circle of the dial.			ft.	in.		fath.	ft.	in.
162°	= ∠18° 0′	S. of E.	36	0	or	6	0	0
143°¾	= ∠36° 15	S. of E.	44	4	or	7	2	4
16°½	= ∠73° 30′	N. of E.	30	9	or	5	0	9
257°¼	= ∠12° 45′	S. of E.	28	6	or	4	4	6
45°	= ∠45° 0′	N. of E.	17	10	or	2	5	10
7°¾	= ∠82° 15′	N. of W.	15	3	or	2	3	3
152°½	= ∠27° 30′	S. of E.	72	0	or	12	0	0
87°½	= ∠ 2° 30′	N. of E.	16	0	or	2	4	0
204°½	= ∠65° 30′	S. of W.	73	0	or	12	1	0

Required the distance and bearing of the extreme points A C.

OPERATION.

Bases southerly.

deg.			ft.	in.		fath.	ft.	in.		ft.	in.
18	0′	=	1	10·24922	×	6	0	0	=	11	1·49528
36	15′	=	3	6·57429	×	7	2	4	=	26	2·57669
12	45′	=	1	3·89021	×	4	4	6	=	6	3·44849
27	30′	=	2	9·24590	×	12	0	0	=	33	29·5080
65	30′	=	5	5·51721	×	12	1	0	=	66	5·12605
										143	3·59725

Bases northerly.

deg.			ft.	in.		fath.	ft.	in.		ft.	in.
73	30′	=	5	9·03502	×	5	0	9	=	29	5·80448
45	0′	=	4	2·91169	×	2	5	10	=	12	7·14507
82	15′	=	5	11·34234	×	2	3	3	=	15	1·33685
2	30′	=	0	3·14060	×	2	4	0	=	0	8·37150
										57	10·65790

		ft.	in.
From bases southerly	=	143	3·59725
Subtract bases northerly	=	57	10·65790
Departure B C		85	4·93935

Perpendiculars easterly.

deg.			ft.	in.		fath.	ft.	in.		ft.	in.
18	0′	=	5	8·47607	×	6	0	0	=	84	2·85642
36	15′	=	4	10·06401	×	7	2	4	=	35	9·02851
73	30′	=	1	8·44910	×	5	0	9	=	8	10·80163
12	45′	=	5	10·22464	×	4	4	6	=	27	9·56704
45	0′	=	4	2·91169	×	2	5	10	=	12	7·14507
27	30′	=	5	3·86478	×	12	0	0	=	63	10·37736
2	30′	=	5	11·93147	×	2	4	0	=	15	11·81724
										199	1·59327

Perpendiculars westerly.

deg.			ft.	in.		fath.	ft.	in.		ft.	in.
82	15′	=	0	9·70926	×	2	3	3	=	2	0·67815
65	30′	=	2	5·85791	×	12	1	0	=	30	3·27124
										32	3·94939

		ft.	in.
From perpendiculars east	=	199	1·59327
Subtract perpendiculars west	=	32	3·94939
	A B	166	9·64388

	ft.	in.
Perp. or east and west line, A B	166	9·64388
Base south of east C B	85	4·93935

Then by construction (as before) the hypothenuse A C will be found 187 feet, 3 inches, and the angle *p q* 27 degrees, south of east.

THE PRACTICAL MINER'S GUIDE.

PART II.

INTRODUCTION.

Several years have elapsed since "The Practical Miner's Guide" was sent into the world, and the author is constrained to acknowledge that his extensive practice and experience, in almost every branch of mining, during that long period, has not enabled him to discover where any important improvement can be made in that work. The *additions* in the present volume are comprised in merely extending the principles originally laid down, and practically applying the mathematical tables and rules to more difficult, complicated, and momentous subterranean surveys; for it may be remarked, without subjecting ourselves to the charge of arrogancy, that the *light* thrown on the mining world by this publication has contributed towards expanding the minds of practical men generally, and qualifying them for pursuing and carrying out the scientific and demonstrative principles to the utmost extent of their difficult and highly important operations.

During the last five years the author commenced a correspondence on mine surveying in the "Mining Journal," with a view of rendering a lasting benefit to the mining interest, by exposing the imperfection of the old methods of dialling, by *tracing*, *pegging*, or mechanical repetition, and showing the vast superiority of the trigonometrical system in every point of view. This attempt brought on a most extensive controversy, and many of "the old school" arose and came forward to advocate the old practice; but, as if ashamed of the cause they had espoused, they were, almost to a man, anonymous writers.

The unprejudiced and investigating part of the community honored me, or rather the system I defended, with their able support, and rallied around my standard. The defeat of our opponents was complete, even before we attempted to apply the infallible test of *experimental operation*. Reason and historical proof had thrown them down; but when we brought forward problems, in the shape of actual surveys, and challenged them to furnish the true answers, they crept out of the field, and not one of them was heard of after that interesting, beneficial and satisfactory investigation was introduced. Nearly all the problems that appear in this supplement were publicly brought forward by the author on this occasion, and of course underwent a rigid and extensive scrutiny; and, so far from any error appearing, the truth of the calculation and perfection of the system was demonstrated by exact corresponding solutions being publicly recorded from persons residing in England, Ireland, and Wales.

It will be seen, in the preface to the first edition of this work, that I called public attention to the great injury done to mining by the bad practice of surveying or dialling then in general use; but as at that time there was no work written on the subject, there was an excuse for the disastrous errors that took place then, that does not now exist; and the mine agent who cannot now *prove* all his dialling operations, before a single stroke has been struck, ought not to presume to make the attempt; and certainly it behooves directors, managers, and shareholders in mines, to test the abilities of those agents or captains who profess to be competent to undertake the momentous work of subterraneous surveying, by requiring them to give mathematical solutions to a series of practical questions on the subject; and not, as is too often the case, proving their incapacity by some fearful error that they have committed, occasioning serious injury to the mine, great delay, and an extra cost of hundreds of pounds to the proprietors. And let it be understood, that *proof* cannot be obtained by the old method of dialling; that is, by tracing or repeating at the surface the drafts taken underground. This was fully demonstrated in the course of the late controversy, both argumentative and practically. One convincing case was brought forward, and confirmed, that occurred several years ago. It was required to find the point at surface for sinking a shaft to meet a rise that had been commenced at the adit level. This was certainly a very plain and easy job under a good system, but it presented insurmountable difficulties under the old practice. The shaft was set to a pair of eight men, and the captains proceeded to *dial* and *peg* to ascertain the true point. The first dialler fixed his terminating peg on a certain spot, and the next dialler's peg occupied another position; and, the history of the case is, that four agents were constantly occupied two or three weeks about this job, without being able to ascertain the true place for the shaft, which a competent man would have determined and proved in a few hours. At the close they had a plantation of pegs occupying an area of several square fathoms; and the manager seeing it hopeless to expect *certainty* from such an *uncertain* practice, and tired of waiting and wasting any more time, proceeded to make the best of a bad matter, by lining out the shaft in the place where the pegs appeared to stand thickest! and the consequence was, a serious error of some feet in the holing.

Now, by introducing this affair, our design is not to impeach *men:* it is the *practice* or usage that we condemn and expose, in order that it may be discountenanced and rejected, and thereby an incalculable benefit be conferred on metallic mining.

TRAVERSE DIALLING.

It is well known that our mine agents or captains have almost to a man been selected from the "ranks," and have been brought up as working miners from their youth; and the best judges admit the propriety and even necessity of this regulation, in order that they should be competent to fix the value or fair price for working a tut-work bargain, or tribute pitch, and possess a thorough knowledge of underground operations. This being admitted, we must conclude, that in general their education has been much limited; and, therefore, in writing for their assistance, although there may be some exceptions, we would accommodate ourselves to the lowest capacity, so that the young aspiring miner may not be discouraged from prosecuting his incumbent and laudable studies, and qualifying himself for performing the high and paramount duties of a mine agent with credit to himself, and advantage to his employers and his country.

Before this work was published, it is questionable whether a mining traverse had ever been trigonometrically solved in this country; and, consequently, in order to simplify the matter, the instructions given for finding the ultimatum of a course of dialling was by construction or instrumental operation; but as we believe our students are generally prepared to advance a step, we shall now recommend and show the more excellent way of performing the whole by computation, or by figures.

The trigonometrical method of working a course of dialling reduces the whole, however numerous and diversified, into two numbers; for the four columns of easting, westing, northing, and southing being added up separately, and then the lesser deducted from the greater of the opposite cardinal points, reduces the whole into two numbers, forming the base and perpendicular of the great triangle, and are necessarily right angle cardinal bearings, such as easting and southing, or northing and westing, as the case may be; and our next and last operation is to find the hypothenuse and angle corresponding with these two sides, which hypothenuse and angle is the final line, or course of the survey.

EXAMPLE.

A traverse has been worked, the columns added up, and the westing subtracted from the easting, showing the excess of easting to be 346 feet; and the southing subtracted from the northing, the difference proved the excess of northing, 419 feet 5 inches.

OPERATION.

Find the hypothenuse by square root.

Rule.—Add the sum of the squares of the two sides together, and extract the square root of their sum.

```
      346          419·4
      346          419·4
     ----          -----
     2076         16776
    1384          37746
   1038           4194
   ------        16776
   119716        ----------
                 175896.36
                 119716
                 ----------
                 295612·36 (543·7
                 25              12
                 ---            ----
           104) 456             8·4
                416
                -----
          1083) 4012
                 3249
                ------
         10867)  76336
                 76069
                 -----
                   267
                 -----

                ft.  in
    Answer Hyp. 543  8
```

Find the angle by proportion.

```
      ft.  in.        ft.              ft.
    If 419  5 gives  846  what will    6 give?
        12            12               12
      ----          ----               --
      5033          4152               72
                      72
                    ----
                    8304
                   29064
                  ------            in.      ft.  in.
           5033) 298944 (59·39  or  4   11·39
                 25165
                 -----
                  47294
                  45297
                  -----
                   19970
                   15099
                   -----
                    48710
                    45297
                    -----
                     4413
                    -----
```

Then by inspection in the second table, page 79, this quotient of 4 feet 11·39 inches will be found standing opposite 39° 30′, which is the bearing, or sum of the angle opposite the shortest side of the great triangle.

ANSWER.

Hypothenuse, or direct length from beginning to end, 543 feet 8 inches. Bearing, or direction from beginning to end, 39° 30′ east of north.

REMARKS.

In carrying out this system practically, after we have laid down this grand or final line at surface, and fixed a mark at the extreme end of the line which has been measured off from the starting point, 543 feet 8 inches on the bearing, 39° 30′ east of north, (or 50° 30′ north of east, the complement,) we are furnished with a double means of proving if this length and angle has been correctly laid down, by measuring off, due north, 419 feet 5 inches from the start, and then placing the theodolite, or dial, on the end of that line, and measuring off due east 346 feet; consequently, if the whole has been well done, the last mark will exactly agree in both cases. Or should the ground be more favorable, we may avail ourselves of the convenience of laying off the east line first, and the north line last, which will bring us to the same point.

One great advantage of these proof lines will appear, when we take into consideration that most of the instruments used in mines for taking horizontal angles have no vernier scale for reading off the fraction of the angle; and, therefore, if the bearing falls between any quarter, or half of a degree, the surveyor must depend on the judgment of his eye for the division, and let it be known that an error of one quarter of a degree in 100 feet amounts to 5 inches and a decimal of ·23596, or upwards of 2 feet 7 inches in a line of 100 fathoms; hence the value of having this most satisfactory and convenient check for the laying down of the last grand line must be manifest to every observer, and should never be neglected.

LOGARITHMS.

Should the practitioner wish to prove the finding of the angle and hypothenuse by logarithms, the following is the rule:—

From less side 346 and radius	=	12·5390761
Subtract longest side, 419·4	=	2·6227140
Log. tangent of 39° 30′		9·9163621

RULE FOR THE HYPOTHENUSE.

From less side and radius (as before)	12·5390761
Subtract sine of 39° 30′	9·8035105
Logarithm of 543·8 nearly	2·7355656

The rules expressed at length read thus:—

FOR THE ANGLE.

Add the radius to the logarithm of the less side, and from the sum subtract the logarithm of the greatest side; the remainder, or sum, will be the tangent of the angle opposed to the less side.

FOR THE HYPOTHENUSE.

Add the logarithm of the given side to the sine of the angle opposite to the side required, and from the sum subtract the sine of the angle opposed to the given side; the remainder will be the logarithm of the side required.

SYSTEM.

There is much propriety in the remark, that "system is the handmaid of science," and the term may be considered as used in contradistinction to disorder, irregularity, or random. The man who would excel in the important work of mine-surveying should have a *system*, and a good one. It is true, men are apt to be bigoted in this matter, and think so highly of their own system as to despise all other; but certainly we must admit that a bad or an imperfect system is better than no system at all. He who has no fixed rule is liable to error every step he takes. We would recommend the young dialler to adopt a system in keeping his register, or dialling book underground, so that his subterranean surveys may be perfectly clear and comprehensible, not only to with the vernier precisely at the same point, and then, throwing off the needle, perform all the remainder of the traverse by means of the outer circle. Hence it will be evident, then, if the outward circle is also graduated toward the right hand, that the whole course will come under the immediate operation of the "converting table," as if the work had been performed with the needle; and if the graduation should be reversed, the "left-hand" bearings will apply accordingly, regard being had to inversion in both cases.

This instrument is also well adapted for taking the bearing of diagonal or underlaying shafts, having a lift of iron pumps; a job that has often baffled the skill and ingenuity of diallers, and occasioned numerous and most serious errors.

The operation may be performed thus:—Suppose we are in the 60 fathom level, and from thence to the 100, the shaft was sunk on the course of the lode, on an underlay of 3 feet per fathom northerly. By applying the instrument at some point in the level near the shaft (but far enough away to be free from attraction by the pumps), we find the bearing by the needle, to a point opposite the shaft, to be due west, and the vernier on the outer rim standing at 90°; we then remove the instrument to the shaft, where the light was held, and adjust the back observation as before directed, having 90° on the outer rim, and the needle thrown off as useless, because we are now close to the pumps. A light is to be carried down the shaft as far as it can be seen, and after the graduated circle has been screwed fast, the rack is applied, and the sights turned until we cut the candle in the bottom of the shaft. This being done, we examine and read off the degree against the point of the vernier, which proves to be (say) 187¾°. Now, as when the instrument stood in a due west position the outer circle stood at 90°, and in taking the bearing, it stood at 187¾°, therefore, by subtracting 90° from 187¾°, we find the gain to the right hand of west is 97¾°, and, the underlay being northerly, the true bearing of the shaft is 7¾° east of north.

The imperative call for accuracy in cases of this kind, will be seen when it is considered that the diagonal part of this shaft is upwards of 40 fathoms, and the underlay 3 feet in a fathom, consequently, the whole base is more than 20 fathoms; and an error in the bearing has the same effect on the survey as if it had been made in taking a horizontal draft of 20 fathoms long, and on which an error of 4° would throw the end of the line nearly 9 feet too far either to the right or left.

Should a dialler be called to do a job of this kind in the absence of a suitable instrument, he may accomplish it in the following manner:—Let him fix a cross-staff in such a position that, through one pair of sights, he can see the candle in the shaft, and in the line of the other pair, he has the dial fixed in the level, out of the way of the attraction; consequently, the light in the shaft, and the dial in the level, are two objects forming a right angle with his cross-staff. He then requests his assistant to look at a light held immediately over the head of his cross-staff, through the sights of the dial, and he finds this (say) 12° north of west; and as the bearing of the shaft is exactly at right angles with this line, if the underlay is northerly, the bearing of the shaft will be 12° east of north, if southerly, 12° west of south. The best cross-staffs, or instruments, for the express purpose of taking right angles, are now made of a hollow cylindrical shape, of brass, with cuts or apertures for taking the observation; but a substitute may be used on a pinch, by drawing two lines at right angles on a board, about 6 inches square and an inch thick; let these lines be cut half an inch deep with a fine saw, and then fix it on a three-feet stand; if the lines are truly drawn and cut, this rough instrument will serve until a better one can be procured.

CONSTRUCTION.

The old method in laying down a traverse was by drawing a parallel line, and removing the protractor at every draft. The evils of this practice are too glaring to require remark.

Fix your protractor, and lay off as many drafts as will come within the convenient range of your parallel ruler; number them in order as they stand in your dialling book; remove the protractor, and lay off the first draft from the centre direct; then apply the protractor to the centre, and No. 2, and make the parallel movement until you touch the end of the last line, or No. 1, and then draw and point off the length of No. 2, and so on through all the drafts you have pointed off from the protractor.

The advantages of laying down or pointing off a number of drafts at one fixing of the protractor, and then applying them in their true length and position, is most conspicuous; and the geometrician will testify of its superiority, both as it regards accuracy and expedition.

CONVERTING TABLE.

Remarks on the following table for converting the degrees recorded in the dialling book of an underground survey into the bearings.

All practical men are aware of the difficulty, hazard and delay, that attends an attempt to obtain the bearing of every draft underground, in a long and complicated survey. The best process is to record the degree, or angle only, at which the needle settles, and after the work is finished underground; then convert the various angles into the real bearing or true direction of each draft, and we may remark, that the bearings *must* be obtained if the work is to be mathematically proved. But as it is not an easy matter to turn a long course of dialling into the bearings, with an assurance of being correct, this table has been constructed for that express purpose; and its utility, simplicity, and perfection has been acknowledged by many practical men.

EXPLANATION.

All circumferentors (dial or miner's compass) are not graduated alike. In all cases, 360° stands at the north point, and 180° at the south; but some are figured toward the right hand, from the north point (which we call a "right-hand dial"), and others toward the left-hand, so that a "right-hand dial" has 90° at the east point, and a "left-hand dial" has 90° at the west point. This diversity of graduation has often caused much perplexity and confusion among diallers. The following table is contrived to suit both sorts of instruments; and is so plainly arranged and marked, as to require but little explanation. It must be specially regarded, that the table has been constructed upon the consideration that the eye of the surveyor has been applied to the south sight or vane standing against 180°; this must be invariably the case. Hence the north sight must always take the lead, and the young practitioner may here be told that in dialling a level and making double, or fore and back drafts, at every station, that although his eye must be placed at the *north* sight, necessarily, for the back observation, yet as the dial has not been turned, the needle will stand to the true degree for the record, and no confusion or liability to error can occur.

In converting an underground survey, or any other, from angles into bearings, it is obviously our first object to know the graduation of the instrument by which the work has been performed; and if it has been a "right-hand dial," and the first draft was on 167°, the bearing would be 13° west of south, but if it was done by a "left-hand dial" the bearing would be 13° east of south. The only thing where a liability to error at all exists in obtaining the bearings by inspection from this table, and where caution is required, is in applying the fractions of degrees when they occur in the drafts. On these occasions, observe that when the angle and bearing progress alike, as in all the left-hand side of the column, then the fraction must be *added* to the whole number of the bearing; but otherwise, as in the right-hand side, the fraction must be *deducted* from the whole number. Lastly, the following desirable proof may be resorted to:—If the course has been correctly converted, the degree and bearing added together or subtracted from each other will make one of the following numbers:—0, 90, 180, 270, 360; and this may be done almost at a glance after the survey has been converted into bearings.

TABLE FOR CONVERTING ANGLES INTO BEARINGS.

Rt. Hd. Dial. W. of N. Lt. Hd. Dial E. of N.			Rt. Hd. Dial N. of W. Lt. Hd. Dial N. of E			Rt. Hd. Dial S. of W. Lt. Hd. Dial S. of E.			Rt. Hd. Dial W. of S. Lt. Hd. Dial E. of S.		
Angle.		Bearing.	Angle.		Bearing.	Angle.		Bearing.	Angle.		Bearing.
1	is	1	46	is	44	91	is	1	136	is	44
2		2	47		43	92		2	137		43
3		3	48		42	93		3	138		42
4		4	49		41	94		4	139		41
5		5	50		40	95		5	140		40
6		6	51		39	96		6	141		39
7		7	52		38	97		7	142		38
8		8	53		37	98		8	143		37
9		9	54		36	99		9	144		36
10		10	55		35	100		10	145		35
11		11	56		34	101		11	146		34
12		12	57		33	102		12	147		33
13		13	58		32	103		13	148		32
14		14	59		31	104		14	149		31
15		15	60		30	105		15	150		30
16		16	61		29	106		16	151		29
17		17	62		28	107		17	152		28
18		18	63		27	108		18	153		27
19		19	64		26	109		19	154		26
20		20	65		25	110		20	155		25
21		21	66		24	111		21	156		24
22		22	67		23	112		22	157		23
23		23	68		22	113		23	158		22
24		24	69		21	114		24	159		21
25		25	70		20	115		25	160		20
26		26	71		19	116		26	161		19
27		27	72		18	117		27	162		18
28		28	73		17	118		28	163		17
29		29	74		16	119		29	164		16
30		30	75		15	120		30	165		15
31		31	76		14	121		31	166		14
32		32	77		13	122		32	167		13
33		33	78		12	123		33	168		12
34		34	79		11	124		34	169		11
35		35	80		10	125		35	170		10
36		36	81		9	126		36	171		9
37		37	82		8	127		37	172		8
38		38	83		7	128		38	173		7
39		39	84		6	129		39	174		6
40		40	80		5	130		40	175		5
41		41	85		4	131		41	176		4
42		42	87		3	132		42	177		3
43		43	88		2	133		43	178		2
44		44	89		1	134		44	179		1
45		45	90		R. H. D. W. Lt. H. D. E.	135		45	180		South.

TABLE FOR CONVERTING ANGLES INTO BEARINGS.

Rt. Hd. Dial E. of S. Lt. Hd. Dial W. of S.		Rt. Hd. Dial S. of E. Lt. Hd. Dial S. of W.		Rt. Hd. Dial N. of E. Lt. Hd. Dial N. of W.		Rt. Hd. Dial E. of N. Lt. Hd. Dial W. of N.	
Angle.	Bearing.	Angle.	Bearing.	Angle.	Bearing.	Angle.	Bearing.
181	is 1	226	is 44	271	is 1	316	is 44
182	2	227	43	272	2	317	43
183	3	228	42	273	3	318	42
184	4	229	41	274	4	319	41
185	5	230	40	275	5	320	40
186	6	231	39	276	6	321	39
187	7	232	38	277	7	322	38
188	8	233	37	278	8	323	37
189	9	234	36	279	9	324	36
190	10	235	35	280	10	325	35
191	11	236	34	281	11	326	34
192	12	237	33	282	12	327	33
193	13	238	32	283	13	328	32
194	14	239	31	284	14	329	31
195	15	240	30	285	15	330	30
196	16	241	29	286	16	331	29
197	17	242	28	287	17	332	28
198	18	243	27	288	18	333	27
199	19	244	26	289	19	334	26
200	20	245	25	290	20	335	25
201	21	246	24	291	21	336	24
202	22	247	23	292	22	337	23
203	23	248	22	293	23	338	22
204	24	249	21	294	24	339	21
205	25	250	20	295	25	340	20
206	26	251	19	296	26	341	19
207	27	252	18	297	27	342	18
208	28	253	17	298	28	343	17
209	29	254	16	299	29	344	16
210	30	255	15	300	30	345	15
211	31	256	14	301	31	346	14
212	32	257	13	302	32	347	13
213	33	258	12	303	33	348	12
214	34	259	11	304	34	349	11
215	35	260	10	305	35	350	10
216	36	261	9	306	36	351	9
217	37	262	8	307	37	352	8
218	38	263	7	308	38	353	7
219	39	264	6	309	39	354	6
220	40	265	5	310	40	355	5
221	41	266	4	311	41	356	4
222	42	267	3	312	42	357	3
223	43	268	2	313	43	358	2
224	44	269	1	314	44	359	1
225	45	270	R. H. D. E. L. H. D. W.	315	45	360	North.

APPLICATION OF THE CONVERTING TABLE.

Suppose the needle stood at 246½°, what is the bearing?

Answer { By a right-hand dial 23½° South of E.
By a left-hand dial 23½° South of W.

It may be remarked, that the table is equally applicable for changing bearings into angles if required. For example:—An observation was made with a right-hand dial, and the bearing found to be 27° 17′ E. of N., at what degree did the needle point?

Ans. 332° 43′, and if proof is required it will be seen that the sum of these degrees and minutes is 360°.

EXAMPLE.

Convert the following angles taken with a left-hand dial into bearings:—

210¼° 176¾° 305½° 28⅛° 107⅛° 97½°

Operation.			Proof.
210¼° is	30¼°	W. of S.	210¼° — 30¼° = 180
176¾	3¼	E. of S.	176¾ + 3¼ = 180
305½	35½	N. of W.	305½ — 35½ = 270
28⅛	28⅛	E. of N.	28⅛ — 28⅛ = 0
107⅛	17⅛	S. of E.	107⅛ — 17⅛ = 90
97½	7½	S. of E.	97½ — 7½ = 90
348	12	W. of N.	348 + 12 = 360

EXAMPLE.

Convert the following angles taken with a right-hand dial into bearings:—

9° 45′ 239° 25′ 331° 12′ 160° 58′ 45° 6′

Operation.			Proof.
9° 45′ is	9° 45′	W. of N.	9° 45′ — 9° 45′ = 0
239 25	30 35	S. of E.	239 25 + 30 35 = 270
331 12	28 48	E. of N.	331 12 + 28 48 = 360
160 58	19 2	W. of S.	160 58 + 19 2 = 180
45 6	44 54	W. of N.	44 54 + 45 6 = 90

N.B.—In practice it would not be necessary or convenient to *state* proofs—it is introduced here for the learner's sake, that he may be enabled to insure certainty in this essential matter.

In pressing on our young mining friends the advantage of adopting a perfect system, we advise that, in preparing a course of dialling for trigonometrical solution, by changing the angles into bearings, care should be taken that all the drafts should be made either to exceed 45°, or that they should all stand below, or at least not exceed that half quadrant. Our reason for being urgent on this matter is, that there may be a uniformity in placing the sides in the traverse table after the draft has been computed. And let it be particularly noticed that, if the bearings are not suffered to exceed 45°, that the *last* expression of the bearing will signify the *longest* of the two sides. That is, suppose a draft taken underground was 287¼°, measuring 45 feet 8 inches; now looking at the "converting table" we see that if this draft was taken with a "left-hand dial," that the bearing is 17¼° north of west (or N. of W.) and the two sides will be found by computation to be 13 feet 7 inches, and 43 feet 7 inches. Query, into what columns respectively must these numbers be placed? As the bearing was north of west, and our system states that "the last expression of the bearing will signify the longest of the two sides," consequently the longest side (43 feet 7 inches) must be placed in the "*west*" column, and 13 feet 7 inches in the north column.

If this order is followed up, it will render the working of traverses (which is the most important operation in mine surveying) a plain, pleasing, and satisfactory exercise. In this edition we would needs bring forward every thing likely to promote the advancement of the young mining officer in this paramount branch of his profession, and therefore give him to understand that, in traversing, there must be a regular course from beginning to end.

We shall make ourselves understood in this matter, by taking a case where a person makes a survey for the purpose of ascertaining the length and bearing of a level driven on an east and west lode; and, for some convenient purpose, he begins his dialling at some point about the middle of the level, and dials from thence to the eastern end; he then returns to the station or start at the middle of the level, and dials on to the western end, and thus completes the survey.

Now if he was to proceed to work the traverse from his dialling book in this state, his results would appear as if his level was almost without length or bearing, as his eastings would be balanced by his westings, &c.

In order to go *systematically* to work in this case, his first operation must be to *reverse* the order of one or the other of the diallings; that is, if he pleases to let the first remain, which is the eastern dialling, and would accommodate the western part to suit the other, he must alter or reverse all the drafts, by converting (say) 16° south of west into 16° north of east, and so of all the rest.

In winding up this course of instruction, we will take a short survey, and go through with it at length, and the student may accompany us if he pleases; for we are of the opinion that practical teaching is the best.

EXAMPLE.

It is required to sink a vertical shaft on the end of a level, and the diallings from the bottom of an old downright shaft are as follows:—

Surveyed with a "right-hand" dial.

			fath.	ft.	in.
No. 1.	356¼°	Length	18	3	0
2.	84¼		12	1	6
3.	98		15	4	0

		fath.	ft.
4.	A Winze 322° Underlay 25½°, Inclined length	11	2

5.	107¼° Length	25	5	6	End.

This is the underground work, and our first operation is to find out the underlay of the winze, in order that it may stand as a common draft in the survey.

OPERATION.

The underlay, or angle made by the dip of the winze and a vertical line, being 25½ degrees, we find it standing in the first table against 2 feet 7 inches, showing that every fathom of the winze gives a base of 2 feet 7 inches, and the length of the winze being 11 fathom 2 feet, we multiply

		ft.	in.
⅓)		2	7
			11·2
4		4	5
			10
4		5	3

Here we find the base of the winze to be 4 fath. 5 ft. 8 in.

The next thing is to refer to the converting table to reduce the drafts into bearings; taking special notice that the work was done with a right-hand dial.

We therefore find that No.	1.	356¼°	is	3¾° E. of N.
	2.	84¼		5¾ N. of E.
	3.	98		8 S. of W.
Winze	4.	322		28 E. of N.
	5.	107¼		17¼ S. of E.

Our work is now prepared for entry in the traverse table as data for trigonometrical computation.

No.	Angles and Lines.		Trigonometrical Results.			
Draft.	Bearings.	Lengths.	East.	West.	North.	South.
		fath. ft. in.				
1	3¾° E. of N.	18 3 0				
2	5½ N. of E.	12 1 6				
3	8 S. of W.	15 4 0				
4	28 E. of N.	4 5 3				
5	17¾ S. of E.	25 5 6				

The above is the table with the bearings and lengths of the drafts entered in order for receiving the trigonometrical results in their proper and respective columns, and that every thing may be clear to the learner we shall let this table remain as it is, and make a similar one, in which the computations are entered, and proceed to take out the tabular numbers from the first mathematical table, and multiply them by their respective lengths.

FIRST DRAFT.

ft. in.	ft. in.
7 3¾° Tabular 0 4.7	Tabular 5 11·85
6	6
2 2.2	35 11·10
3	3
6 6·6	107 9·30
3	2 11·92
6 8·9 Easting.	110 9·2 Northing.

Now the sides of the triangle formed by the first draft are ready to be transferred to the east and north columns of the traverse table.

SECOND DRAFT.

ft. in.	ft. in.
∠5½° Tabular 0 6·9	Tabular 5 11·67
12¼	12¼
6 10·8	71 7·92
1·7	1 11·42
7 0·5 Northing.	73 7·3 Easting.

When the bearing does not diverge much from the cardinal point, there is but little difference between the length of the hypothenuse and the longest of the legs, as in the right-hand sides of the above two drafts.

THIRD DRAFT.

```
              ft. in.                  ft.  in.
∠8° Tabular   0 10·02       Tabular    5   11·3
                    8                        8
             ————————                 ————————
              6  8 16                 47    6·4
                    2                        2
             ————————                 ————————
             13  4·32                 95    0·8
                 3·31                  1   11·8
             ————————                 ————————
             13   1·0 Southing.       93    1·0 Westing.
             ————————                 ————————
```

The length of the draft being 15 fathom 4 feet, we have multiplied by 16, and deducted ⅓ as the shortest method.

FOURTH DRAFT, OR BASE OF WINZE.

```
               ft. in.     in.              ft. in.     in.
∠28° Tabular   2   9·8 or 31 8   Tabular    5   3·6 or 63·6
                            5                            5
                        ———————                     ———————
                        169·0                        318 0
                          4·2                          7·9
                        ———————                     ———————
                    12) 164·8                    12) 310·1
                        ———————                     ———————
                        13 8·8 Easting.             25·10·1 Northing.
                        ———————                     ———————
```

In the above, it will be seen that we have thrown the tabular length into *inches* and parts, and the practitioner will find this, in general, the easiest way of calculating.

FIFTH DRAFT.

```
                 ft.  in.     in.             ft.  in.     in.
∠17¼° Tabular    1   10·0 or 22·0   Tabular   5    8·6 or 68·6
                               26                          26
                           ———————                    ———————
                            132                         411·6
                            44                         1372
                           ———————                    ———————
                            572·0                      1783 6
                              1·8                         5·7
                           ———————                    ———————
                       12) 570·2                  12) 1777·9
                           ———————                    ———————
                            47·6·2 Southing.          148·1·9 Easting.
                           ———————                    ———————
```

Now the computations are ready for entry in the following table:

No.	Angles and Lines.				Trigonometrical Results.							
Draft.	Bearings.	Lengths.			East.		West.		North.		South.	
		fath.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1	3¼° E. of N.	18	3	0	6	8·9	.	.	110	9·2		
2	5¼ N. of E.	12	1	6	73	7·3	.	.	7	0·5		
3	8 S. of W.	15	4	0	.	.	93	1·0	.	.	13	1·0
4	28 E. of N.	4	5	3	13	8·8	.	.	25	10·1		
5	17¼ S. of E.	25	5	6	148	1·9	.	.	.	.	47	6·2
					242	2·9	93	1·0	143	7·8	60	7·2
					93	1·0			60	7·2		
					149	1·9	Easting.		83	0·6	Northing.	

Now we might proceed to lay down the position or place of our new vertical shaft at the surface without any further operation. For by measuring off from the centre of the old shaft at surface 149 feet 2 inches, due east, and from the end of that line measuring 83 feet due north, would bring us exactly over the end of the fifth or last draft, where the shaft is to come down, but we would work out the direct length and bearing also, as before described, and apply it.

PROBLEM.

A new vertical shaft was commenced which is intended to intersect the main lode at the depth of 100 fathoms below the adit level, which is about 40 fathoms from surface in the vicinity of the new shaft. From a point in this level, a drift or cross-cut has been begun, and designed to be driven in a direct line to the centre of the new shaft, and from thence to rise against it, if necessary; and the aim and object of the survey is to ascertain the exact length and bearing of the said cross-cut, as every proper means have been adopted to certify that it has been commenced at the nearest point of the shaft.

The following is the whole course of dialling in its most simplified form, with the irregular surface lines reduced to horizontal measure, the angle of every draft converted into bearing, and the whole given in complete order for working the traverse without any preliminary preparation. The draft standing on the top of 934 feet is from the centre of the new shaft at surface to a line hung in the old engine shaft, which is also vertical to the adit, and the next draft is taken from that line in the adit and continued to the end of the 34th draft, through the same level, where the cross-cut commences.

It is also required to furnish the *bearing* of the lode from the 3d to the 34th draft inclusive.

REMARKS.

As this course of dialling has been rendered so plain, there appears to be no occasion to introduce a double entry of it, as the field and underground work is sufficiently manifest in the first three columns of the following table, in combination with the trigonometrical operation. It may be satisfactory to the student to be informed that this work has been accomplished and proved to be perfectly correct. The cross-cut was driven all the way (50 fathoms) through a hard granite country, at nearly $5,000 cost, and occupied full two years of uninterrupted labor.

COMPUTATION.

No.	Angles and Lines.			Trigonometrical Results.							
Drafts	Bearings.	Lengths.		East.		West.		North.		South.	
	From new Shaft to Engine Shaft.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
	14° 18′ S. of W.	934	0	.	.	905	0·7	.	.	230	8·3
1	13¾ S. of E.	30	0	29	0·7	.	.	.	.	7	1·6
2	4¾ E. of S.	80	6	2	6·3	.	.	.	.	30	4·8
	On course of lode										
3	5¼ S. of E.	28	6	28	4·5	.	.	.	.	2	8·8
4	4 N. of E.	42	6	42	4·7	.	.	2	11·6		
5	16 S. of E.	30	8	29	5·8	.	.	.	.	8	5·4
6	2¼ do.	32	0	31	11·7	.	.	.	.	1	4·7
7	18¼ do.	29	2	27	8·9	.	.	.	.	9	1·6
8	4¼ do.	18	0	17	11·5	.	.	.	.	1	4·0
9	3¼ N. of E.	36	0	35	10·2	.	.	2	2·4		
10	13 S. of E.	17	0	16	6·8	.	.	.	.	3	9·9
11	19¾ do.	26	6	24	11·2	.	.	.	.	8	11·4
12	14 do.	22	7	21	11·0	.	.	.	.	5	5·6
13	15 do.	36	3	35	0·1	.	.	.	.	9	4·6
14	1 do.	46	6	46	5·9	.	.	.	.	0	9·8
15	17 N. of E.	41	3	39	5·4	.	.	12	0·7		
16	4 do.	11	2	11	1·7	.	.	0	9·3		
17	21¼ do.	12	8	11	9·4	.	.	4	7·7		
18	1 do.	27	0	27	0·0	.	.	0	5·7		
19	2 do.	38	8	38	7·7	.	.	1	4·2		
20	1 S. of E.	18	0	18	0·0	.	.	.	.	0	3·8
21	20 do.	12	6	11	8·9	.	.	.	.	4	3·4
22	7 do.	11	6	11	5·0	.	.	.	.	1	4·8
23	1 do.	25	8	25	8·0	.	.	.	.	0	5·3
24	4 N. of E.	31	6	31	5·1	.	.	2	2·3		
25	13 S. of E.	34	6	33	7·4	.	.	.	.	7	9·1
26	1 N. of E.	18	8	18	8·0	.	.	0	3·9		
27	5 do.	28	0	27	10·7	.	.	2	5·3		
28	8 S. of E.	65	0	64	4·4	.	.	.	.	9	0·6
29	2 do.	36	6	36	0·4	.	.	.	.	1	8·3
30	5 do.	18	0	17	11·2	.	.	.	.	1	6·8
31	6¼ N. of E.	24	8	24	6·0	.	.	2	9·5		
32	1 do.	12	3	12	3·0	.	.	0	2·6		
33	18 do.	29	6	28	0·7	.	.	9	1·4		
34	12 do.	20	1	19	7·8	.	.	4	2·1		
				899	6·1	905	0·7	45	8·7	345	9·6
						899	6·1			45	8·7
				Westing		5	4·6	Southing		300	1·9

Then by the foregoing method of proceeding, the required answers will be found as follows:—

Length of cross-cut from adit to centre of shaft, 300 feet 2 inches.

Bearing of cross-cut 1° 2′ west of north.

Bearing of lode from 3d to 34th draft, inclusive, 2½° south of east.

PROBLEM.

A lode was opened on the back by costeening in several places, and its course, by compass, found to be 10¼° south of east; but this was on the ascent of a steep hill whose angle of elevation was 16½°, and the lode underlaying northerly three feet in a perpendicular fathom.

Query. What is the true bearing or course of the lode? and what would be the amount of error in carrying on the line 600 fathoms (horizontal measure) supposing the run of the back of the lode on the ascent had been taken, by mistake, instead of the true horizontal course?

OPERATION.

We find in the first table that 16½° of elevation gives 1 ft. 8·45 in. perpendicular, and 5 ft. 9·04 in. base for the corresponding sides of the triangle.

```
          ft.              ft.                       ft.  in.
Hence If 6 perp. gives 3 underlay, what will 1   8·45 give?
         12              12                      12
         --              --                      ----------
         72              36                      20·45
                                                   36
                                                 --------
                                              72) 736·20 (10·2
```

Showing that the underlay of the lode carries the line 10 1–5 inches further north than the line taken at the surface (or bearing) on every horizontal line of 5 ft. 9·04 in. Therefore we have the two sides of a right-angled triangle 5 ft. 9·04 in. and 10·2 in., and the angle opposite the shortest side will be the amount of the angle of error.

```
 ft.   in.       in.       feet.
As 5  9·04  :   10·2  : :   6
   12                      12
  -----                   -----
  69·04                    72
                           10·2 in.
                          -----
                 69·04) 734·4 (10·63
```

By inspection of the 2d table we find the nearest next less angle standing opposite this number (10·63 in.) is 8° 15′, giving 10·44 in.; and as the difference between this and the next greater (8½) is ·32, and the difference between 10·63 in. and 10·44 in. is ·19, we say,

As ·32 is to ·19, so is 15′ = 9′.

And 9′ added to 8° 15′ gives 8° 24′ for the angle of error; and by deducting this angle of error (if it may be so called) from the course of the lode on the inclined surface (10½ south of east), we have 2° 6′ south of east for the true bearing of the lode; and as the error is 10·64 in. in a horizontal fathom, this number multiplied by 600, gives 6384·00 inches, or 88⅔ fathoms, too far south, on a line of 600 fathoms.

REMARKS.

We beg to call the particular attention of our mine agents to this case. The vast sums of money expended every year in costeening for right-angle open cuttings at the surface in searching for lodes, is well known to practical men; and probably there is no branch of mining in which there is a greater waste of time and money. Workmen are often put to costeen at random, when a scientific survey might have put them in a position for opening the lode in a few hours which has occupied them for weeks or months, and at the last all their labors fraught with doubt and uncertainty; but these are not the worst consequences arising from ignorance or inattention to this subject. I know a rich mine in this county, where the angle of ascent was made in error, and carried on to find the lode in the adjoining set, and the effect was, that they pitched to cut the lode in the new set nearly 200 fathoms out of the line; and they have been driving now nearly five years through a hard country at a cost of some thousands of pounds, and have not yet cut the lode! Volumes might be written on the errors that have taken place from this source; and probably there is not a man of experience to be found but what can confirm the report with his testimony.

PROBLEM.

In a 20 fathom level driving on an east and west lode, underlaying north, a winze has been commenced bearing due north, and it is determined to pitch a rise against it in the 40 fathom level (the 30 fathom level not having been driven far enough east to rise from). The following is a statement of the dialling from the middle of the above winze, in the twenty, through the level west towards another winze sunk to the 30 fathom level.

No.	deg.	ft.	in.	No.	deg.	ft.	in.
1	282¼	59	10	3	264¼	83	4
2	286	61	8	4	260¼	77	3

This brings us to the brace of the winze communicating with the 30 fathom level, which we may call No. 5, its diagonal length

65 feet, underlay, 22½ degrees; bearing, 9½° east of north. From the foot of this winze in the 30, the dialling is continued westerly to another winze communicating with the 40 fathom level; viz.

No.	deg.	ft.	in.
6	272½	60	9
7	256	52	0
8	287½	45	8

We now arrive at the brace of the winze to the 40 which we call No. 9,—length, 70 ft. 6 in.; underlay, 31½°; bearing, 4° west of north. From the bottom of this winze in the 40, the course turns easterly, and is continued in that direction; viz.

No.	deg.	ft.	in.	No.	deg.	ft.	in.
10	83	85	4	13	90	77	6
11	77	28	5	14	92½	23	8
12	104½	76	0	15	99	107	2

At the end of this 15th draft we place an assumed mark in the back of the 40 fathom level.

Question. It is requested to know how far we must measure east or west from this mark in order to arrive at the exact point for rising against the winze sinking from the 20 fathom level? also what will be the average underlay at that place, and what will be the length of the winze from the 20 to the 40 fathom level?

COMPUTATION.—(SURVEYED WITH A LEFT-HAND DIAL).

No.	Angles and Lines.				Trigonometrical Results.							
Draft.	Degree.	Bearing.	Length.		East.		West.		North.		South.	
			ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1	282½	12½° N. of W.	59	10	.	.	58	6	12	8	.	.
2	286	16 N. of W.	61	8	.	.	59	3	17	0	.	.
3	264½	5½ S. of W.	33	4	.	.	38	2	.	.	3	2
4	260½	9½ S. of W.	77	3	.	.	76	2	.	.	13	1
5	Winze.	9½ E. of N.	24	10	4	0	.	.	24	6	.	.
6	272½	2½ N. of W.	60	9	.	.	60	8	2	8	.	.
7	256	14 S. of W.	52	0	.	.	50	6	.	.	12	7
8	287½	17½ N. of W.	45	8	.	.	43	7	13	7	.	.
9	Winze.	4 W. of N.	36	10	.	.	2	7	36	9	.	.
10	83	7 N. of E.	85	4	84	8	.	.	10	4	.	.
11	77	13 N. of E.	28	5	27	8	.	.	6	5	.	.
12	104½	14½ S. of E.	76	0	73	8	.	.	.	.	18	9
13	90	East.	77	6	77	6	.	.	.	.	.	.
14	92½	2½ S. of E.	23	8	23	8	.	.	.	.	1	0
15	99	9 S. of E.	107	2	105	10	.	.	.	.	16	9
					397	0	384	5	123	11	65	4
					384	5			65	4		
			Easting		12	7	Northing.		58	7		

Now we discover, by the foregoing calculation, that our assumed mark in the 40 fathom level is 12 feet 7 inches *too far east* for the central point of the rise against the winze sinking from the twenty, and which was the paramount object required.

NOTE.—As the last draft (reversed) is 9° N. of W., in order to be quite accurate, it will require us to measure 12 feet 9 inches back through the level to make good 12 feet 7 inches westing, and this will give 1 foot 10 inches more of base or northing, which, added to 58 feet 7 inches, the underlay shown, by the column of northing will give the answer to the question, 60 feet 5 inches for the whole underlay.

The first operation in working this problem is to find the base and perpendicular of the two winzes, numbers 5. and 9., and their respective bases form the operative lines in the above traverse.

	ft.	in.		ft.	in.	
Winze No. 5. gave	24	10	basa, and	60	1	perpendicular.
Winze No. 9. gave	36	10	base, and	60	1	perpendicular.
				120	2	

Now the vertical depth being 120 ft. 2 in., and the base or northing 60 ft. 5 in., we have thus the two sides of a right-angled triangle to find the hypothenuse and dip or angle of declination, which on trial will be found—

Hypothenuse, or length of winze, 134 feet.
Angle, or underlay of winze, 26½ degrees.

PROBLEM.

A tunnel has been commenced at the foot of a hill, and is intended to be driven through it.

The bearing from the above point, or the course of the tunnel, is to be due east, and it is required to know the exact corresponding point on the other side of the hill, in order to set another company of men to drive a *dead* level to meet the drivings that are progressing from the west side.

The length of the tunnel is also required.

The following is the survey from the first point.

No		deg.		ft.
1	Elevation	14	Length	26
2	——	12¼	——	26
3	——	11	——	17
4	——	18¼	——	90
5	——	10	——	60
6	——	7½	——	119
7	Horizontal	0	——	29
8	Depression	5¾	——	28
9	——	16	——	230

Judging that we have now arrived somewhere near the level or horizontal plane of the start, or that our "depressions" have made good our "elevations," we place an assumed mark at the end of the last or 9th draft, and retire to work out our lines and angles by trigonometry.

OPERATION.

	Perp.		Base.	
fath. ft.	ft.	in.	ft.	in.
No. 1 Elevation 14 deg. Length 4 2 Tabulars	1	5·4	5	9·9
		4½		4½
	5	9·6	23	3·6
		5·8	1	11·3
	6	3·4	25	2·0

Thus we find the 1st draft gives a rise or elevation of 6 feet 3·4 inches, and base or horizontal length 25 feet 2·9 inches; and proceeding in the same manner with all the drafts, and finding the difference between the elevations and depressions, we shall obtain true data for correcting our assumed mark, and replacing it in its proper position.

		Elevation.			Horizontal.	
		ft.	in.		ft.	in.
No. 1	gives	6	3·4	and	25	2·9
2		5	6·2		25	4·9
3		3	2·9		16	8·3
4		28	6·0		85	4·0
5		10	5·0		59	0·1
6		14	8·5		118	1·0
		68	8·0			
7					29	0·0
		Depression.				
8	gives	2	8·2		27	10·5
9		63	3·8		220	3·0
		66	0·0		606	10·7

Now as the depressions are 2 feet 8 inches less than the elevations, it demonstrates that our assumed mark is 2 feet 8 inches too high, and as the declination of the ground from the last draft eastward continues on the same angle of depression of 16 degrees, we have perpendicular 2 feet 8 inches and angle 16° to find the corresponding hypothenuse and base; and by inspection of the 2d table we see that the "tabulars" opposite 16° are 1 foot 8·6 inches, and 6 feet 2·9 inches hypothenuse.

Therefore, if 1 foot 8·6 inches give 6 feet 2·9 inches, what will 2 feet 8 inches give?

Which will be found to give 9 feet 8 inches of hypothenuse.

And by the 1st table it will be found that 9 feet 8 inches of hypothenuse on an angle of 16° will give for the longest side, or base, 9 feet 4 inches.

ADJUSTMENT.

By removing the assumed mark 9 feet 8 inches, due east on the slope, we fix on the exact spot for commencing the eastern end of the tunnel, and we need hardly observe, that the two extreme marks mean the bottom or floor of the tunnel.

Then by adding the base, 9 feet 4 inches, made by the corrections to the sum of the horizontals, 606 feet 10·7 inches, we have just 616 feet 3 inches for the length of the tunnel.

Note.—Should it be required to put down vertical shafts on the tunnel, the foregoing computations reveal what their depths would be respectively at all parts of the tunnel, and the deepest shaft would be 11 fathoms 2 feet 8 inches at the end of the 6th draft, and 55 fathoms from the western mouth of the tunnel.

PROBLEM.

It is intended to sink a shaft on the end of a level driven from Pendarves' shaft, and the following is the survey from the centre of Pendarves' shaft to the end of the level; viz.

No.	deg.		ft.	in.
1	3	W. of N.	45	0
2	7¼	N. of E.	24	6
3	8¼	N. of E.	18	0
4		East	49	1
5	12	S. of E.	30	0
6	6¼	S. of E.	27	0
7	15	S. of E.	16	5
8	5	N. of E.	21	0
9	12¼	N. of E.	14	7
10	9	W. of N.	28	0

As profound accuracy is required in this case (it being intended to facilitate the work by rising against the new shaft from the end of the level), a reverse or proof course of dialling has been made from the end back to the centre of Pendarves' shaft; viz.

No.	deg.		ft.	in.
1	8¼	E. of S.	26	10
2	11	S. of W.	15	0
3	4¼	S. of W.	19	6
4	13¼	N. of W.	20	0
5	9¼	N. of W.	52	3
6	1¼	S. of W.	44	0
7	7	S. of W.	26	0
8	9¾	S. of W.	22	8
9	2¼	E. of S.	43	10

It is now required to know if there is an exact agreement between these two surveys, or fore and back diallings (or what is the difference between them), and if so, what is the length and bearing from the centre of Pendarves shaft, at the surface, to the point exactly over the end of the level where the centre of the new shaft must be fixed?

OPERATION.—FROM PENDARVES' SHAFT TO EASTERN END.

No.	Angles and Lines.		Trigonometrical Results.			
Drafts	Bearings.	Lengths	East.	West.	North.	South.
		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1	3° W. of N.	45 0	. .	2 4·2	44 11·2	. .
2	7¼ N. of E.	24 6	24 3·7	. .	3 1·1	. .
3	8½ N. of E.	18 0	17 9·6	. .	2 7·9	. .
4	East	49 1	49 1·0	. .	. .	. .
5	12 S. of E.	30 0	29 4·1	. .	. .	6 2·8
6	6¼ S. of E.	27 0	26 9·8	. .	. .	3 2·1
7	15 S. of E.	16 5	15 10·3	. .	. .	4 3·0
8	5 N. of E.	21 0	20 11·0	. .	1 10·0	. .
9	12¼ N. of E.	14 7	14 3·0	. .	3 1 1	. .
10	9 W. of N.	28 0	. .	4 4·6	27 7 9	. .
			198 4·5 6 8 8	6 8·8	83 3·2 13 7·9	13 7.9
		Easting	191 7·7	Northing	69 7·3	

FROM EASTERN END TO PENDARVES' SHAFT.

No.	Angles and Lines.		Trigonometrical Results.			
Drafts	Bearings.	Lengths	East.	West.	North.	South.
		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1	8½° S. of E.	26 10	8 11·6	. .	. .	26 6·5
2	11 S. of W.	15 0	. .	14 8·7	. .	2 10 3
3	4¼ S. of W.	19 6	. .	19 5·2	. .	1 7·4
4	13¼ N. of W.	20 0	. .	19 5·6	4 7·0	. .
5	9½ N. of W.	52 3	. .	51 6·5	8 7·5	. .
6	1¼ S. of W.	44 0	. .	43 11·9	. .	0 11·5
7	7 S. of W.	26 0	. .	25 9·7	. .	3 2·0
8	9¼ S. of W.	22 8	. .	22 4·1	. .	3 10·1
9	2¼ E. of S.	48 10	1 8·6	. .	. .	43 9·6
			5 8·2	197 3·7 5 8·2	13 25	82 9·4 13 2·5
			Westing	191 7·5	Southing	69 6·9

Now we find that as the westing and southing of the back dialling corresponds with the easting and northing of the direct dialling to the fraction of an inch, it amounts to a mathematical demonstration of the perfection of the underground survey. It now only remains for us to obtain the hypothenuse and angle opposite the base of the two given sides of the triangle formed by the easting 191 feet 7¾ inches, and northing 69 feet 7 inches, which will be found to give :—

Length (from centre of Pendarves' shaft to point over end), 203 feet 11¼ inches.
Bearing, 20 degrees north of east.

N.B.—After this length and bearing has been applied at the surface, and the point fixed for the centre of the new shaft, an infallible and desirable proof that this last and important work has been done correctly may be obtained, by availing ourselves of the ready means placed within our reach by the cardinal points or sides of the great triangle. Thus, by measuring off from the centre of Pendarves' shaft 191 feet 7¾ inches due east, and then from the end of that line 69 feet 7 inches due north, the end will fall exactly on the point fixed at the end of the line 203 feet 11¼ inches on the bearing of 20 degrees north of east, if the whole has been done correctly.

162099

PLANS AND SECTIONS OF MINES.

Persons who have not had practical experience in mining often acknowledge that they find great difficulty in comprehending the plans and sections of a mine, or of having a true idea of the workings from an inspection of the drawings. This obscurity may be occasioned from an imperfection in the plans; for if they have been executed under a good *system*, it can hardly fail to exhibit clearly every part of the workings, and, indeed, if the diagrams have not been executed perfectly, and according to rule and order, even miners themselves cannot comprehend them. It requires four distinct mathematical or geometrical drawings to represent a mine, which we will briefly notice under each head; and we may observe, as we pass on, that the common cause of people in general not understanding the plans is because they expect to know too much from one single drawing. Every separate plan exhibits both a true and false view of some parts of the mine; and the knowledge necessary for the observer is, what parts of the workings it is that each drawing furnishes a true delineation of.

With this introduction we proceed to state that the set of drawings may be described thus:—

1. Ground plan.
2. Horizontal or working plan.
3. Longitudinal section.
4. Transverse section.

And taking them in the order in which they have been placed, we begin with—

(1.) THE GROUND PLAN.

This is, in the main, a general survey of the whole set, or land granted to the adventurers for the purpose of mining. This plan may be on a scale of three or four chains to an inch; and every landowner's bounds should be distinctly marked on this map.

All the lodes are laid down with their true position and course on this plan, as far as they can be ascertained; and we may remark, that this survey should be made at the outset or plant of a mine, and before any thing has been determined as to the position of an engine shaft, or any other important work, so that the manager may have the benefit of this map, with the lodes, cross courses, and every necessary thing faithfully delineated thereon, to assist his judgment in forming the most judicious arrangement for future operations. For want of this precaution, how often is it that shafts have been sunk in improper places, to the endless disadvantage of the company; and sometimes they have been abandoned and new shafts sunk, at a fearful loss of time and money! In fact, we believe there are but few mines where the conductors have not had cause to regret, ultimately, that they had not taken another position for sinking the principal shafts, and which might have been known, at the outset, if the necessary steps had been pursued.

On this map it should be particularly pointed out if there is any intervening ground on the course of the lodes, that has not been legally granted, so that proper applications may be made in due time, and not leave it until the workings have been commenced, and good discoveries made, and then this landowner, taking advantage of the neglect or oversight, demanding an unreasonable premium and dues for his land, or prohibiting us from driving an inch under it, on pain of knocking us to pieces with the powerful arm of the law.

(2.) HORIZONTAL OR WORKING PLAN.

This is the miner's plan, his chart, his guide, his right hand. Whoever attempts to conduct the operations of a mine without a perfect working plan, is unfit for his office. The very circumstance of his supposing himself capable of doing so, is a certain proof of his ignorance.

This plan gives, what surveyors call, "a bird's-eye view" of the mine; or let us suppose that the ground was transparent, and by walking over every part at the surface we could look down and distinctly see all the workings.

A person who never saw a mine will understand from this view that he could distinguish the course of the levels in all their turns and windings, and, as respects all the "horizontal" drivings, he would have a *true* view of them; but these drivings are the *only* thing that he would obtain a true view of in this plan.

Keeping his position in view, he hardly requires to be told, that he can only see the brace or mouth or base of all the vertical or downright shafts, even if they were 200 fathoms deep.

As for the diagonal shafts or winzes (which are small ventilating shafts sunk on the declination of the lode from level to level), he would only see the "underlay" of them, or the distance that they diverge from a perpendicular line. As lodes, almost if not altogether without an exception, have a dip or declination, called by miners "underlay," it follows that the levels are generally removed away from the vertical line, and not concealed one by another, although this is sometimes partially the case when there is a reverse or change of underlay. In addressing myself to the miner, in reply to his question or inquiry respecting the best method of constructing and keeping up a working plan, I will endeavor to explain the system I always adopt, and which I believe is the best, at least I have found it so, after thirty years' experience. Let the scale be five fathoms to an inch. Before you begin to lay down any part of the workings, draw faint lines throughout the whole length and breadth of your sheet of drawing paper at right angles, forming two-inch squares; these lines will be your cardinal points. If your lode bears east and west, the longest way of the paper will of course be appropriated for that bearing. These lines are always to remain; and as they are to be single, and fine, and the course of your levels drawn with double lines, they will not in the least confuse, especially as your levels must be distinctly and variously colored between the double lines (which represent the breadth of the level), so that every level, with all its drifts and connections, may be distinguished in a moment or two, however numerous or complicated your levels and drivings may be. One grand advantage of these cardinal cross lines is, that every intersection forms a proper and suitable point for laying on the centre of the double-limb protractor, or any other, on all occasions, so that in keeping up the plan or laying down any additional drafts, there is always a point close at hand for the protractor, without the inconvenience and risk of bringing on a north and south line, for the purpose, from a distant part of the paper. Another convenience of these lines is, that the bearing of the lode, or any part of it, may, by their help, be obtained in a few seconds; for instance, as every side of one of the squares gives 10 fathoms, when a level has been laid down, we can, by inspection, see very nearly (and by the application of a scale exactly) what it has diverged to the right or left from the main course, and if we find it to be (say) 125 fathoms east, and 19½ fathoms north, the tables will tell us that the bearing is 8° 50′ north of east; and, by the same means, we may always check or prove the truth of the plan or the construction by trigonometrical computation, and which should always be done before the plan is relied on, or pronounced perfect.

This plan, proved and well kept up, becomes invaluable to the mine agent. Does he want to sink a winze in one level and rise against it in another? Every thing he can wish for is before his eyes. The two corresponding points for the sink and rise, the amount of underlay, the bearing, the length of the winze and its vertical depth, are all embodied in the plan. Has the lode split, and have the workmen driven on the wrong branch? look at the plan, and compare notes with the general bearings, and the course to be adopted will be apparent. I have known a case where the plan betokened that a misdriving had taken place in a level, but the agent persisted that the driving was right in spite of the plan; however the manager, having more confidence in *computation* than in *conceit*, was convinced by the indications of the plan that they were gone off the main branch, and ordered them immediately to "turn house," or cut north at right angles: this was done, and in driving two fathoms, the main lode was discovered with a large and rich course of copper ore.

(3.) LONGITUDINAL SECTION.

This drawing supposes that a section of the ground has been cut away, and that a side view of the mine is exposed. If it is an east and west run, the observer is placed at the south of the mine, and taking a panoramic north view of all the excavations.

In this position he will have a perfect sight of all the vertical shafts, and a general view of the stopes, or ore ground broken away between the levels, also the dip of the courses of ore may be portrayed and distinguished, and the surface line of the country, with a perspective view of the buildings and machinery, may be seen or exhibited fairly by this section. But the levels, diagonal shafts, cross-cuts, and winzes, will have a false or imperfect appearance here. For instance, the levels will *appear* to be perfectly straight, however serpentine or crooked their course may be. The diagonal shafts and winzes will appear to be perpendicular, because their dip is in the line of the inspector's eye; and as an *end* view will be taken of the north and south cross-cuts, the extent of these drivings will not be seen.

The only real benefit of this section to the miner is, that it may be so contrived as to show the dip, or inclination, or declination, of the bunches or courses of ore, and this circumstance he may turn greatly to his advantage in working the mine. For example, suppose in driving the 50 fathom level, going east, we cut into a course of ore, and it lasted 25 fathoms in length; let these two points of the "coming in" and "going out" of the course of ore be correctly marked in this 50 fathom level of this section.

In the 60 fathom level, or next level below, the same course of ore was cut 4 fathoms farther west than it was in the 50, and the course of ore at this level proved to be 28 fathoms long. Let these points also be marked on the section, and as there is a general regularity in the dip of ores, the agent is now in possession of a clue, whereby he may form a reasonable judgment at what place the course of ore will come in at the 70 fathom level, or levels still deeper, and also at what point it will fail in driving east, hence he will be better qualified for setting tribute with the help of this section than if he had no such guide. The longitudinal sketches that are usually shown in mines, with a pell-mell blotch of the stopes, and, as we have shown, the false view of the levels, diagonals, and winzes, are useless to the miner, and deceptive to the stranger.

(4.) TRANSVERSE SECTION.

Here the view is taken at one end of the workings. Suppose again the drivings to be east and west, and the dip of the lode northerly, the observer is placed at the west end, with his face easterly. Now, for the first time, he will have a fair view of the declination of the shafts and winzes that have been sunk on the course of the lode, and thereby he will see all the dip and variations of the lode from the surface to the bottom of the mine. Here he will see the northing and southing made by the cross-cuts, and if a vertical shaft is in sinking to take the lode at a certain depth, the point of intersection will be apparent to his view. Respecting the levels driven on the course of the lode, he will only see their western end. If there has been no diagonal shaft, but the mine has been worked by a downright sump or engine-shaft, this section will exhibit a regular and correct view of all the drifts or cross-cuts, from the shaft to the lode, and from this data, or the extreme ends of the cross-cuts, the declination of the lode will be conspicuous. The transverse view of the surface line will finish all that can be fairly seen by this drawing.

OBSERVATIONS.

After such a detail we think there will be no occasion for "summing up," or repeating to the inquisitive stranger, or adventurer, what may be seen, and what may not be seen, on each and every drawing. To the practical man, or with him, we may converse of the best and readiest means of making these drawings. Let us suppose the horizontal or working plan to be drawn and executed, and proved in a correct and masterly manner, and all the vertical shafts truly *dropped* or measured. We are then in possession of every thing necessary for drawing the two sections without going out of the office; for by parallels, or a drawing board and slides, all the shafts, winzes, &c., may be transferred from the plan to the paper prepared for the sections, with despatch and accuracy. True, we may have recourse to the dialling book for the position, length, height, and depth of the stopes and sinks; and if a perspective drawing of that part of the set where the buildings are placed should be required, a sketch must be made for that purpose.

To the learner we would observe, that, if he is about to survey a mine and draw a working plan, let him lay down his shallow adit, or the upper levels, first, and the others in succession; because, wherever any *crossings* take place, or one level or draft passes immediately under another, the upper level must be entire or unbroken, and the under level will not be shown, as a matter of course, being necessarily obscured or concealed by that partof the workings that passes immediately above it. One method of proving his work as he proceeds is as follows:—Suppose he has surveyed the adit level, and there are four winzes communicating with the 10 fathom level, and he has taken the bearing, and depression, and length of those winzes, and plotted or laid down this level and the true base of those winzes on his working plan. He then proceeds to survey the 10 fathom level, making good every thing as he proceeds; and of course when he arrives at the foot of those winzes which he surveyed in the adit, he minutely enters in his dialling book the mark at their foot, where he took his diagonal observation and measurement. Then in laying down his 10 fathom level, if all his work has been well done, the points in those winzes will exactly correspond with his survey in the 10 fathom level and on the plan, and this desirable check he may and should pursue throughout the whole survey. It is too common in these cases, in order to avoid the time and labor in surveying the winzes to "let them take their chance," by merely entering their "brace" in one level and "foot" in another, and let the truth of their respective bearings and underlay depend on the horizontal survey of the levels. This practice is reprehensible, and should never be tolerated. But, with all this precaution, we advise, by all means, that every part of the plan be proved by trigonometrical computation, and the surveys by fore and back diallings. Let us suppose we have surveyed a level by double diallings. How shall we ascertain if there is a perfect correspondence? We have introduced a problem on this subject, and it is plain that the final two sums of the traverse will demonstrate either the agreement or the difference. This being done, and the underground work proved correct, we proceed to construct or draw the level on the plan, and it is most desirable that we should know if this part of the work has been well executed; as we have computed the workings, we are furnished with a ready and certain test. Suppose we found, by computation, that the level gave, from beginning to end, 184 fathoms 3 feet of southing, and 34 fathoms 4 feet of westing. Now, applying these numbers to the plan, we shall, by the convenient help of the cardinal lines and instruments, presently prove if the latitude and longitude between the start and terminus of the level on the plan make good these lines. Lastly, I would recommend that the instruments for drawing and keeping up the working plan should be a

6 or 7 inch circular protractor, on the best principle, with double limb and vernier scale for reading off the angle, so that there may be no *guessing*, or judging by the eye, merely, for the fractional part of the degree; also, a parallel ruler of the best kind. I prefer those rulers that travel on rollers, both for expedition and accuracy, but I admit it requires some practice to use them well. There is an advantage in those rulers, in that they have an ivory edge and a graduated scale, so that the lengths may be pointed off at the same time that the line is drawn, without using a compass or dividers; and these two instruments are all that are required for the drawing department. The parallel ruler should be a foot long, divided into thirty feet to an inch; so that any line within the extent of 360 feet can be pointed off at once.

THE PRACTICAL MINER'S GUIDE.

PART III.

INTRODUCTION.

THE qualifications necessary to constitute an accomplished miner are more numerous and difficult of attainment than is generally imagined, even by persons deeply interested in mining affairs; and although it may not be expected that every one who fills a mining situation should be an adept in all the various branches of the art, yet it is certainly highly desirable that agents, who have the management of large adventures, should possess a general knowledge of every thing connected with the profession of a miner.

The following miscellaneous subjects are essential to the practical miner, and require no comment to set forth their utility; they may also be found useful and interesting to persons not immediately engaged in mining pursuits.

The first article consists in a description of the art of assaying silver; and as this has hitherto been a secret in the possession of but few persons, it is expected that it will form an acceptable part of the work, especially as it will come abroad at a time, when foreign mining speculations (where the seat of action is principally among the precious metals) abound beyond all precedent.

The next part of the work contains a plain statement of the method of assaying copper, including the established process of one of the most experienced and respectable copper-assayers in the county of Cornwall.—Rules for assaying lead and tin follow in succession, and this part of the treatise concluded with a description of the manner of extracting silver from copper ore, or of discovering the quantity of silver it contains; and probably this article also may be productive of beneficial effects to the mining interest, as there is great reason to believe that a considerable proportion of silver is contained in the ores produced from many of our copper mines. The method is very simple, and the trial may be quickly and satisfactorily made.

The subsequent part of the work is described in the table of contents.

ASSAY OF SILVER ORE.

Sample—1 ounce avoirdupois, pulverized and sifted through a fine hair sieve, then well mixed in the scoop with the following flux, viz.:

Red lead*	2 oz.
Red tartar	5 dwts.
Nitre	9 dwts.
Borax	4 dwts.
Lime	¼ oz.
Salt	2 oz.
Fluor spar (bruised)	¼ oz.

Smelt the ore in a wrought-iron crucible; if this cannot be conveniently procured, and a stone pot used, add 1 ounce of iron. The sample will melt in a good heat in about 12 minutes, if the ore is tolerably free from sulphur and iron, otherwise it will require more time.

When the sample has become quite fluid, take it out and pour it in a mould prepared to receive it, having been anointed on the inside with grease or oil; the process of taking out and pouring the sample must be done quickly, otherwise a degree of chill will take place, so that the metal will not run freely out of the crucible, and the assay will in consequence be imperfect.

If the operation has been properly managed, the lump will separate clean from the slag or dross by a slight blow; but if the metal and dross stick together, the assay is impure:—it is probable a little more nitre would remedy this defect.

Should the lump when broken display the metal disseminated throughout and uncombined among the slag, it is a proof the sample was not sufficiently flowed, or not kept time enough in the furnace.

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* An ounce of red lead generally contains about 1-32d part of a grain of silver, or nearly 3 ounces of silver in a ton. Derbyshire lead ore is preferred, by some assayers, to red lead.

The proportion of silver contained in the flux must first be known, and the regular deduction made from the produce, in order to obtain a true assay.

If the heat is too strong, or the sample left too long time in the fire, it will set, or become dry and callous, and this change will take place to all appearance quite suddenly. Either the former circumstance of too low a heat, or this of too high, renders the assay irremediable.

Should the sample appear stubborn and refuse to melt in a brisk heat, add more nitre.

TESTING OR REFINING PROCESS.

The test or cupel should be composed of four-fifths bone ashes to one-fifth fern ashes, damped and well beat into an iron ring 2½ inches deep, and 6 inches in circumference.

The test should be put in the fire an hour or more before the refining process is begun, otherwise the silver will be apt to be agitated by the unsettled test, spring over, and consequently the assay be destroyed.

Should the assay set in refining before it has become pure, throw in about half an ounce of potter's lead.*

If the fire is permitted to get low, or too much air admitted into the furnace, the assay will be apt to turn to litharge; whenever this happens, increase the fire by putting in a few pieces of sea-coal instead of coke, at the same time sprinkle a little coal-dust on the test.

When the assay is thoroughly pure or fine it will assume a globular shape, set, or become fixed, and in a few moments will throw up sprouts or branches from the top. Take out the test, weigh the prillion, find in the table the produce or value per ton, and the work will be complete.

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* The fire should be gradually increased toward the close of the process. A muffle or arched cover to the test would prevent the air from taking an unfavorable effect on the assay, while the furnace is opened for the purpose of increasing the fire, by adding coal, wood, or coke.

ASSAY OF COPPER-ORE.

Sample—400 grains pounded well in a mortar and sifted through a fine hair sieve, put in an earthen crucible, and frequently stirred while in the furnace with an iron rod or paddle. The sulphur will be seen to go off in white fumes; the process must be continued until this evaporation ceases, or nearly so, which will generally occupy from one to two hours. Great attention must be paid during this operation in order that a standard regal may be obtained, which being done, there will be no danger of producing a true assay. The ore during the process, must be kept in a free, sandy state, which will be effected by stirring, and constant regulation of the degree of heat. If the ore becomes moist and begins to stick or adhere to the crucible, it must be immediately taken out of the fire and stirred a short time till this effect has ceased, and then returned. When it has become tolerably free of sulphur, it may be discovered by the evaporation having nearly ceased.[*] This being observed, take it out of the fire, and let it gradually cool in the crucible; and if, when cold, the upper part appears red or brown, and the under part black, it is a proof of its having been well calcined.

This being done, add standard flux; viz.

Borax - - - -	5 dwts.
Lime - - - -	1¼ ladle.[†]
Fluor spar (pulverized) -	1 ladle.

Mix these together with the calcined ore in the crucible, and cover the whole with salt,—let it melt well, and a regal will be produced.

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[*] It is only some very stubborn ores, containing a mixture of metals, or semi-metals, which require to be so effectually roasted or calcined.

[†] Common assaying ladle—diameter ¾ inch, depth ½ inch.

MARKS AND REMARKS.

A good or standard regal is brown, and full of cracks or fissures, and of a spherical shape. Should it come out flat, it is a mark of its not having been well calcined, and may be thrown back again with a small quantity of nitre.

Should a regal come out too low or coarse, (having, when broken, a cinder-like, or cellular appearance,) throw it back with additional nitre: if too high or fine, (having, when broken, a metallic appearance) return it to the crucible with a ladle of sulphur; in either case let it work well together a short time, and in all probability a standard regal will be produced.

A regal may be considered good, which will produce from 8 to 12 in 20, and this quality is easily known by inspection; but if less than 8, or above 12, it would be better to reject it, and begin the process again with a new sample.

Gray, black, and green ores, require a proportion of sulphur, in order to throw them back, as they contain too little of this mineral in their composition to produce a good assay.

Should a regal be too fine, put less nitre with it in refining; and therefore the coarser it is, the more nitre will be required.

FINING PROCESS.

Pound or pulverize the regal, put it in an earthen fining pot, and re-calcine it until perfectly sweet (*i. e.* free from sulphur), which may be discovered both by the appearance and fumigation. Then add

Nitre -	- 3 dwts.	Covered or sprinkled over with salt.
Red Tartar	- 10 ditto.	
Borax -	- 5 ditto.	
Salt -	- 2 ladles	

This brings down the assay into coarse copper. Should it come out having a transparent or horn-like appearance, add 4 dwts. of nitre and a ladle of salt, letting it work well in the fire. Should the assay come out black, plate it, and if the black flies off in flakes or scales, it is a proof of its not having been sufficiently calcined; if not, its color may be attributed to lead, or a mixture of metals; the former defect renders the assay hopeless.

Should it come out clean, put the assay in the pot without flux, and when fluid, take out the pot and shake it gently until the surface assumes an azure or blue appearance; then put

Refining flux* - - -	5 dwts.
(viz. 2 parts nitre, to 1 part white tartar)	
Salt - - - -	1 ladle.

Preparatory to pouring into the crucible, place the refining flux in the mouth or forepart of the scoop and the salt behind; throw it in with the assay and let it melt until the flux settles well down, then pour the copper into one mould, and the slag or scoria into another; return the slag into the same pot with 2 ladles of red tartar, and let it melt well down; take out the prillion and weigh it with the lump for the produce, and the work will be completed.

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* The refining flux should go through a calcining process before it is used; it may be done by putting two parts nitre to one part white tartar in an iron mortar, to which apply a red-hot iron, and stir it therewith until the deflagration has ceased; when cold, powder and sift it.

This operation will prevent any commotion during the refining, which otherwise may be so violent as to cause some of the metal to spring out of the crucible, and thereby the assay be spoiled.

ASSAY OF LEAD ORE.

Sample—1 oz. avoirdupois.

FLUX.

1	common ladle	red tartar.
1	ditto.	spar.
2	ditto.	salt.
½	ditto.	borax.
¼	ditto.	nitre.
½	ditto.	lime.

Mix the flux with the sample and put it in an iron crucible, stir it with an iron rod during the latter part of the process; in about five minutes, in a brisk heat, the sample will be down, provided the crucible was red-hot when the assay was thrown in, which should always be the case.

If the sample, to be tried, weighs four ounces, the proportionate quantity of flux must be added, agreeably with the above statement.

It may be discovered when the sample is ready, by the grating of the rod against the bottom of the crucible in stirring—it should then be immediately taken out and poured. The metal will separate clean from the slag in a good assay.

To assay lead ore for discovering the quantity or proportion of silver it contains, the foregoing method must first be used, and the assay then tested precisely the same way as described for refining a silver sample, page 112. The lead will go off in vapor, and the silver remain in the test.

ASSAY OF TIN ORE.

Sample—Two ounces black tin.

FLUX.

Culm	⅛ weight of sample
Borax	4 dwts.

PROCESS.

If the ore contains a large proportion of iron, add more culm*; when the sample is properly down, or flowed, the surface of the assay in the crucible will be perfectly smooth and motionless; in a strong heat this will occur in about twelve minutes.

When taken out of the fire, stir it well with an iron rod before you pour it; afterwards scrape the crucible, pulverize the scrapings in a mortar, and then van or wash them on a shovel. The prillion of a standard sample will not exceed 2 in 20.

The criterion for the lump is its possessing a malleable quality, or bending to the hammer without breaking.

Grain tin may be treated in every respect as the above, except in the subsequent addition of culm, which will not be required.

METHOD OF DISCOVERING THE PROPORTION OF SILVER CONTAINED IN COPPER ORE.

Sample—One ounce.

FLUX.

1 ladle red tartar.
1 ditto nitre.
½ ditto lime.
½ ditto borax.
1 ditto fluor.
1 ditto red lead.

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* If the sample is very stubborn, add a small quantity of pulverized fluor with the culm.

Well mixed with the ore and melted in a wrought iron crucible,* about eight minutes, in a brisk heat, will be sufficient; the last five minutes the assay should be incessantly stirred with an iron rod: pour the sample and cool it, then break out the lump, and test it in the usual way.

REMARKS.

Soon as the assay begins to flow, the lead, by the power of affinity, will presently attract the silver, or the silver, by the same law, will attach itself to the lead, and this being effected, it only requires the process of refining, or burning off the inferior metals, to find the produce.

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* If a stone crucible be used, one ounce of iron must be added to the flux.

A TABLE

SHOWING THE NUMBER OF OUNCES AND PARTS OF AN OUNCE OF SILVER CONTAINED IN A TON OF ORE, BY ASSAY PRODUCED FROM ONE OUNCE AVOIRDUPOIS.

Assay.	Per Ton.			Assay.	Per Ton.			Assay.	Per Ton.		
grs.	oz.	dwts.	grs.	grs.	oz	dwts.	grs.	grs.	oz.	dwts.	grs.
1-32	2	6	16	6	448	0	0	12⅛	905	6	16
1-16	4	13	8	⅛	457	6	16	¼	914	13	8
⅛	9	6	16	¼	466	13	8	⅜	924	0	0
¼	18	13	8	⅜	476	0	0	½	933	6	16
⅜	28	0	0	½	485	6	16	⅝	942	13	8
	37	6	16	⅝	494	13	8	¾	952	0	0
⅝	46	13	8	¾	504	0	0	⅞	961	6	16
¾	56	0	0	⅞	513	6	16	13	970	13	8
⅞	65	6	16	7	522	13	8	⅛	980	0	0
1	74	13	8	⅛	532	0	0	¼	989	6	16
⅛	84	0	0	¼	541	6	16	⅜	998	13	8
¼	93	6	16	⅜	550	13	8	½	1008	0	0
⅜	102	13	8	½	560	0	0	⅝	1017	6	16
½	112	0	0	⅝	569	6	16	¾	1026	13	8
⅝	121	6	16	¾	578	13	8	⅞	1036	0	0
¾	130	13	8	⅞	588	0	0	14	1045	6	16
⅞	140	0	0	8	597	6	16	⅛	1054	13	8
2	149	6	16	⅛	606	13	8	¼	1064	0	0
⅛	158	13	8	¼	616	0	0	⅜	1073	6	16
¼	168	0	0	⅜	625	6	16	½	1082	13	8
⅜	177	6	16	½	634	13	8	⅝	1092	0	0
½	186	13	8	⅝	644	0	0	¾	1101	6	16
⅝	196	0	0	¾	653	6	16	⅞	1110	13	8
¾	205	6	16	⅞	662	13	8	15	1120	0	0
⅞	214	13	8	9	672	0	0	⅛	1129	6	16
3	224	0	0	⅛	681	6	16	¼	1138	13	8
⅛	233	6	16	¼	690	13	8	⅜	1148	0	0
¼	242	13	8	⅜	700	0	0	½	1157	6	16
⅜	252	0	0	½	709	6	16	⅝	1166	13	8
½	261	6	16	⅝	718	13	8	¾	1176	0	0
⅝	270	13	8	¾	728	0	0	⅞	1185	6	16
¾	280	0	0	⅞	737	6	16	16	1194	13	8
⅞	289	6	16	10	746	13	8	⅛	1204	0	0
4	298	13	8	⅛	756	0	0	¼	1213	6	16
⅛	308	0	0	¼	765	6	16	⅜	1222	13	8
¼	317	6	16	⅜	774	13	8	½	1232	0	0
⅜	326	13	8	½	784	0	0	⅝	1241	6	16
½	336	0	0	⅝	793	6	16	¾	1250	13	8
⅝	345	6	16	¾	802	13	8	⅞	1260	0	0
¾	354	13	8	⅞	812	0	0	17	1269	6	16
⅞	364	0	0	11	821	6	16	⅛	1278	13	8
5	373	6	16	⅛	830	13	8	¼	1288	0	0
⅛	382	13	8	¼	840	0	0	⅜	1297	6	16
¼	392	0	0	⅜	849	6	16	½	1306	13	8
⅜	401	6	16	½	858	13	8	⅝	1316	0	0
½	410	13	8	⅝	868	0	0	¾	1325	6	16
⅝	420	0	0	¾	877	6	16	⅞	1334	13	8
¾	429	6	16	⅞	886	13	8	18	1344	0	0
⅞	438	13	8	12	896	0	0	⅛	1353	6	16

Assay	Per Ton.			Assay	Per Ton.			Assay.	Per Ton.		
grs.	oz.	dwts.	grs.	grs.	oz.	d wts.	grs.	grs.	oz.	dwts.	grs.
18¼	1362	13	8	28	2090	13	8	37¾	2818	13	8
⅜	1372	0	0	⅛	2100	0	0	⅞	2828	0	0
½	1381	6	16	¼	2109	6	16	38	2837	6	16
⅝	1390	13	8	⅜	2118	13	8	⅛	2846	13	8
¾	1400	0	0	½	2128	0	0	¼	2856	0	0
⅞	1409	6	16	⅝	2137	6	16	⅜	2865	6	16
19	1418	13	8	¾	2146	13	8	½	2874	13	8
⅛	1428	0	0	⅞	2156	0	0	⅝	2884	0	0
¼	1437	6	16	29	2165	6	16	¾	2893	6	16
⅜	1446	18	8	⅛	2174	13	8	⅞	2902	13	8
½	1456	0	0	¼	2184	0	0	39	2912	0	0
⅝	1465	6	16	⅜	2193	6	16	⅛	2921	6	16
¾	1474	13	8	½	2202	13	8	¼	2930	13	8
⅞	1484	0	0	⅝	2212	0	0	⅜	2940	0	0
20	1493	6	16	¾	2221	6	16	½	2949	6	16
⅛	1502	13	8	⅞	2230	13	8	⅝	2958	13	8
¼	1512	0	0	30	2240	0	0	¾	2968	0	0
⅜	1521	6	16	⅛	2249	6	16	⅞	2977	6	16
½	1530	13	8	¼	2258	13	8	40	2986	13	8
⅝	1540	0	0	⅜	2268	0	0	⅛	2996	0	0
¾	1549	6	16	½	2277	6	16	¼	3005	6	16
⅞	1558	13	8	⅝	2286	13	8	⅜	3014	13	8
21	1568	0	0	¾	2296	0	0	½	3024	0	0
⅛	1577	6	16	⅞	2305	6	16	⅝	3033	6	16
¼	1586	13	8	31	2314	13	8	¾	3042	13	8
⅜	1596	0	0	⅛	2324	0	0	⅞	3052	0	0
½	1605	6	16	¼	2333	6	16	41	3061	6	16
⅝	1614	13	8	⅜	2342	13	8	⅛	3070	13	8
¾	1624	0	0	½	2352	0	0	¼	8080	0	0
⅞	1633	6	16	⅝	2361	6	16	⅜	3089	6	16
22	1642	13	8	¾	2370	13	8	½	3098	18	8
⅛	1652	0	0	⅞	2380	0	0	⅝	3108	0	0
¼	1661	6	16	32	2389	6	16	¾	3117	6	16
⅜	1670	13	8	⅛	2398	18	8	⅞	3126	13	8
½	1680	0	0	¼	2408	0	0	42	3136	0	0
⅝	1689	6	16	⅜	2417	6	16	⅛	3145	6	16
¾	1698	13	8	½	2426	13	8	¼	3154	13	8
⅞	1708	0	0	⅝	2436	0	0	⅜	3164	0	0
23	1717	6	16	¾	2445	6	16	½	3178	6	16
⅛	1726	13	8	⅞	2454	13	8	⅝	3182	13	8
¼	1736	0	0	33	2464	0	0	¾	3192	0	0
⅜	1745	6	16	⅛	2473	6	16	⅞	3201	6	16
½	1754	13	8	¼	2482	13	8	43	3210	13	8
⅝	1764	0	0	⅜	2492	0	0	⅛	3220	0	0
¾	1773	6	16	½	2501	6	16	¼	3229	6	16
⅞	1782	13	8	⅝	2510	13	8	⅜	3238	13	8
24	1792	0	0	¾	2520	0	0	½	3248	0	0
⅛	1801	6	16	⅞	2529	6	16	⅝	3257	6	16
¼	1810	13	8	34	2538	13	8	¾	3266	13	8
⅜	1820	0	0	⅛	2548	0	0	⅞	3276	0	0
½	1829	6	16	¼	2557	6	16	44	3285	6	16
⅝	1838	13	8	⅜	2566	18	8	⅛	3294	13	8
¾	1848	0	0	½	2576	0	0	¼	3304	0	0
⅞	1857	6	16	⅝	2585	6	16	⅜	3313	6	16
25	1866	13	8	¾	2594	13	8	½	3322	18	8
⅛	1876	0	0	⅞	2604	0	0	⅝	3332	0	0
¼	1885	6	16	35	2613	6	16	¾	3341	6	16
⅜	1894	13	8	⅛	2622	13	8	⅞	3850	13	8
½	1904	0	0	¼	2632	0	0	45	3360	0	0
⅝	1913	6	16	⅜	2641	6	16	⅛	3869	6	16
¾	1922	13	8	½	2650	13	8	¼	3378	13	8
⅞	1932	0	0	⅝	2660	0	0	⅜	3388	0	0
26	1941	6	16	¾	2669	6	16	½	3397	6	16
⅛	1950	13	8	⅞	2678	13	8	⅝	3406	13	8
¼	1960	0	0	36	2688	0	0	¾	3416	0	0
⅜	1969	6	16	⅛	2697	6	16	⅞	3425	6	16
½	1978	13	8	¼	2706	13	8	46	3434	13	8
⅝	1988	0	0	⅜	2716	0	0	⅛	3444	0	0
¾	1997	6	16	½	2725	6	16	¼	3453	6	16
⅞	2006	13	8	⅝	2734	13	8	⅜	3462	13	8
27	2016	0	0	¾	2744	0	0	½	3472	0	0
⅛	2025	6	16	⅞	2753	6	16	⅝	3481	6	16
¼	2034	13	8	37	2762	13	8	¾	3490	13	8
⅜	2044	0	0	⅛	2772	0	0	⅞	3500	0	0
½	2053	6	16	¼	2781	6	16	47	3509	6	16
⅝	2062	13	8	⅜	2790	13	8	⅛	3518	13	8
¾	2072	0	0	½	2800	0	0	¼	3528	0	0
⅞	2081	6	16	⅝	2809	6	16	⅜	3537	6	16

Assay	Per Ton.			Assay	Per Ton.			Assay.	Per Ton		
grs.	oz.	dwts	grs.	grs.	oz.	dwts.	grs.	grs.	oz.	dwts.	grs.
47½	3546	13	8	51¾	3864	0	0	56	4181	6	16
⅝	3556	0	0	⅞	3873	6	16	⅛	4190	13	8
¾	3565	6	16	52	3882	13	8	¼	4200	0	0
⅞	3574	13	8	⅛	3892	0	0	⅜	4209	6	16
48	3584	0	0	¼	3901	6	16	½	4218	13	8
⅛	3593	6	16	⅜	3910	13	8	⅝	4228	0	0
¼	3602	13	8	½	3920	0	0	¾	4237	6	16
⅜	3612	0	0	⅝	3929	6	16	⅞	4246	13	8
½	3621	6	16	¾	3938	13	8	57	4256	0	0
⅝	3680	18	8	⅞	3948	0	0	⅛	4265	6	16
¾	3640	0	0	53	3957	6	16	¼	4274	13	8
⅞	3649	6	16	⅛	3966	13	8	⅜	4284	0	0
49	3658	13	8	¼	3976	0	0	½	4293	6	16
⅛	3668	0	0	⅜	3985	6	16	⅝	4302	13	8
¼	3677	6	16	½	3994	13	8	¾	4312	0	0
⅜	3686	13	8	⅝	4004	0	0	⅞	4321	6	16
½	3696	0	0	¾	4013	6	16	58	4330	13	8
⅝	3705	6	16	⅞	4022	13	8	⅛	4340	0	0
¾	3714	13	8	54	4032	0	0	¼	4349	6	16
⅞	8724	0	0	⅛	4041	6	16	⅜	4358	13	8
50	3733	6	16	¼	4050	13	8	½	4368	0	0
⅛	3742	13	8	⅜	4060	0	0	⅝	4377	6	16
¼	3752	0	0	½	4069	6	16	¾	4386	13	8
⅜	3761	6	16	⅝	4078	13	8	⅞	4397	0	0
½	3770	13	8	¾	4088	0	0	59	4406	6	16
⅝	3780	0	0	⅞	4097	6	16	⅛	4415	13	8
¾	3789	6	16	55	4106	13	8	¼	4424	0	0
⅞	3798	13	8	⅛	4116	0	0	⅜	4433	6	16
51	3808	0	0	¼	4125	6	16	½	4442	13	8
⅛	3817	6	16	⅜	4134	13	8	⅝	4452	0	0
¼	3826	13	8	½	4144	0	0	¾	4461	6	16
⅜	3886	0	0	⅝	4153	6	16	⅞	4470	13	8
½	8845	6	16	¾	4162	13	8	60	4480	0	0
⅝	3854	13	8	⅞	4172	0	0				

METHOD OF COMPUTING THE VALUE OF LEAD AND SILVER ORE.

EXAMPLE.

Required the value of 16 tons, 10 cwt. 2 qrs. of lead and silver ore, the produce for lead being 8 5-8 in 20, and silver 3 7-8 grs. from a four-ounce sample. The price of lead £22 per ton, and silver 5*s*. 3*d*. per oz. Returning charges £6 10*s*. per ton, and lord's dues one-twelfth for lead, and one-eighth for silver.

OPERATION.—LEAD.

```
      tons. cwt. qr.
| ¼ |   16 10  2
|   |          8
    ---------------
|   |  132  4  0
| ¼ |    8  5  1
|   |    2  1  1
    ---------------
  *20) 142 10  2
    ---------------         l.  s.          l.  s.  d.
         7  2  2 at 15 10† per ton  110  2  6
        Deduct dues one-twelfth      9  3  6
                                  ---------              ----------
                                                          100 19  0
```

OPERATION.—SILVER.

By table, (page 119,) produce $3\frac{7}{8}$ is 72 oz. 6 dwt. 16 grs. per ton, ($3\frac{7}{8}\div4=\frac{31}{32}$) and

```
tons. cwt. qrs. oz. dwt. grs.   oz.   s. d.   l.  s.  d.
  7    2   2×72   6   16=514 at 5 3  134 18  6
         Deduct dues one-eighth       16 17  4  118  1  2
                                     ----------------------
                        Answer                  219  0  2
```

METHOD OF COMPUTING THE VALUE OF COPPER ORE.

EXAMPLE.

What is the value of 74 tons, 13 cwt. 2 qrs. of copper ore, the produce, by assay, being 7 1–8, and standard £127 12*s.* 6*d.*?

OPERATION.

```
          l.  s.  d.
| ⅛ |   127 12  6
|   |           7
      -------------
        893  7  6
         15 19  0¾
      -------------
       9·09  6  6¾
         20
       -----
       1·86
         12
      ------
      10·38
```

---

* It is not usual to make any allowance for waste on rich ores.

† Returning charge deducted.

THEN

```
         l. s. d.
From     9  1 10
Deduct   2 10  0 per ton returning charge.
        ---------
         6 11 10
         ton.     l.  s.  d.      tons. cwt. qrs.
Again, If 1   :   6  11  10   : :   74   13   2
```

BY PRACTICE.

```
cwt.                l.  s.  d.
10½ | ½ |           6  11  10
                             9
                   ------------
                   59   6   6
                            8
                   ------------
                  474  12   0
                   13   3   8
                   ------------
                  487  15   8
                    3   5  11
3   | 1/7 |         0  18  10
                   ------------
Answer            492   0   5
```

Copper ores are always computed at 21 cwt. to the ton, the surplus being allowed for waste in carriage, &c.

RULE FOR DISCOVERING THE POWER OF STEAM ENGINES.

1. Square the diameter of the cylinder, multiply the sum by ·7854* and the product by 10:† lastly, multiply again by 144,‡ and the last product will show the number of pounds the engine lifts a foot high in a minute.

---

* The established ratio of the diameter. Or look in the table, page 127, where the square inches contained in a cylinder are given, and take out the number standing opposite the given diameter.

† That is, considering the power equal to 15 lbs. to an inch, and allowing 5 lbs. or one-third for friction.

‡ Considering the stroke to be 8 feet, and the engine to go 9 strokes per minute.

2. A horse is estimated to raise 500 lbs. 64 feet high, or 1000 lbs. 32 feet high, or 32,000 lbs. 1 foot high in a minute; consequently, if the last product be divided by 32,000, the quotient will show the number of horses required to equal the power of the engine.

EXAMPLE.

What is the power, and horse power of a steam engine, the cylinder being 46 inches in diameter?

```
               46+46=2116
                    ·7854
                ---------
                1661·9064
                       10
              -----------
               16619·0640
                      144
          ---------------
32000) 2393145·2160 (75
       224000
       -------
        153145
        160000
        ------
```

ANSWER.

Engine lifts 2,393,143 lbs. one foot high in a minute.
Equal to 75 horses, nearly.

RULE FOR DISCOVERING THE POWER OF A WATER ENGINE.

1.—Multiply the length, breadth, and depth of the bucket together, and divide by 282, (the number of cubic inches in a gallon, beer measure,) multiply the quotient by 10 1–5 lbs. or 10 lbs. 3·2 oz. or 10·2 lbs. the weight of a gallon of water.*

2.—Multiply the diameter of the wheel by 3·1416 (the ratio of the circle), and divide the product by the circular space occupied by each bucket—the quotient will show the number of buckets contained in the wheel.

---

* The result will be the same if the operation is done by the wine gallon, computing it to contain 231 cubic inches, and to weigh 8 lbs. 5·68 oz., or 8·355 lbs.

3.—Multiply the third part* of the number of buckets by the weight of water contained in one, then

4.—For the leverage—From the radius, or half the diameter, deduct the length of the crank, and one-third of the remainder will be the operative length of the lever; multiply the weight of water in one-third of the wheel by this length (taking the feet for the whole number of the multiplier), and the product will show the full, or entire power. Lastly, from this product cast off $\frac{1}{5}$ for friction,† and the remainder will show the net or real power of the wheel.

EXAMPLE.

Required the power of a water-wheel, the diameter being 46 feet, the buckets 30 inches long, 12 inches deep, and 6 inches wide, with $1\frac{1}{4}$ inches between each bucket, and the crank 3 feet long.

OPERATION.

1.—To find the quantity and weight of water in each bucket.

$$30 \times 12 \times 6 = 2160 \div 282 = 7{\cdot}66 \times 10{\cdot}2 = 78{\cdot}13.$$

2.—To find the number of buckets contained in the wheel.

$$46 \times 12 = 552 \times 3{\cdot}1416 = 1734\ (6 + 1\tfrac{1}{4}) \div 7{\cdot}25 = 239.$$

3.—To find the weight of water on $\frac{1}{3}$ of the wheel.

$$239 \div 3 = 80 \times 78{\cdot}13 = 6250.$$

4.—To find the power of the lever.

$$46 \div 2 = 23 - 3 = 20 \div 3 = 6{\cdot}66$$

and

$$6250 \times 6{\cdot}66 = 41625$$

Lastly, for friction.

$$\begin{array}{r} 5)\ 41625 \\ 8325 \end{array}$$

Answer 33,300 lbs., the actual power of the wheel.

---

* There are differences of opinion respecting this; some persons contending that two-fifths the number of buckets are full at a time, but one-third is the most general and the most reasonable proportion.

† Here again engineers are not unanimously agreed, some allowing one-fifth, some one-fourth, and some even one-third of the power, for friction. It is true the distance the wheel is placed from the work, and other contingent circumstances, must be taken into consideration; but in ordinary operations, where the wheel draws close, one-fifth is very near the truth.

To find the depth at which a wheel will draw a column of water in a lift of pumps of any given dimensions.

Rule.—Find the power of a wheel by the foregoing method, then from the table, (page 128) take out the weight of water in a fathom of the given size pump. Divide the power of the wheel (in pounds) by this number, and the quotient will show the fathoms.

EXAMPLE.

The power of the fore-mentioned wheel is 33,300 lbs., how deep will she draw in a 12-inch lift of pumps?

294·53) 33300 (113
Answer 113 fathoms.

TO FIND THE HORSE-POWER OF A WHEEL.

Rule.—Multiply the power (found by the given rule, page 124) by the number of revolutions made by the wheel in a minute, and this product by the length of the stroke in feet, or double the length of the crank: divide the last product by 32,000, and the quotient will show the number of horses required to equal the power of the wheel.

EXAMPLE.

The fore-mentioned wheel is allowed to make seven revolutions in a minute; required the horse-power.

33300
7

233100
6

32·000) 1398·600 (44
128

118
128

Answer, 44 horse power nearly.

TABLE

SHOWING THE SQUARE INCHES CONTAINED IN A CYLINDER, OR CIRCLE, FROM TEN TO SEVENTY-THREE INCHES IN DIAMETER.

Diameter of Cylinder.	Square Inches.	Diameter of Cylinder.	Square Inches.	Diameter of Cylinder.	Square Inches.	Diameter of Cylinder.	Square Inches.
10	78·54	26	530·93	42	1388·59	58	2642·00
11	95·03	27	572·56	43	1452·20	59	2734·00
12	113·10	28	615·75	44	1520·53	60	2827·44
13	132·73	29	660·20	45	1590·43	61	2922·47
14	153·94	30	706·86	46	1661·91	62	3019·00
15	176·71	31	754·77	47	1785·00	63	3117·25
16	201·06	32	804·25	48	1809·56	64	3217·00
17	226·98	33	855·30	49	1885·74	65	3318·31
18	254·47	34	907·92	50	1963·50	66	3421·20
19	283·54	35	962·00	51	2042·82	67	3526·66
20	314·16	36	1017·88	52	2123·72	68	3651·69
21	346·36	37	1075·20	53	2206·19	69	3739·29
22	380·13	38	1134·00	54	2290·23	70	3848·46
23	415·47	39	1194·60	55	2375·83	71	3959·20
24	452·39	40	1256·64	56	2463·00	72	4071·51
25	490·88	41	1320·26	57	2651·76	73	4185·40

Note.—The annexed table of the quantity and weight of water contained in 6 feet of pump may be proved or extended by the following (p. 128) rules; viz.

Square the diameter of the pump and multiply the product, first by the decimal ·7854, again by the length of the pump in inches, and divide by 231; the whole numbers in the quotient will show the wine gallons. Then, to find the cubic feet, divide the solid inches by 1728. Again, to find the weight, multiply the cubic feet by 1000, and divide the product by 16.

EXAMPLE.

How many pounds, wine gallons, and cubic feet, are contained in a cylinder, or pump, 12 inches in diameter, and 6 feet in length?

TO FIND THE WINE MEASURE.

12×12=144 Square of diameter.
·7854 Multiplier

113·0976
6

678·5856
12

Cubic inches in a wine gallon=231) 8143·0272 (35·2512
4

Answer, 35 gals. 1 qt. 1·0048

TO FIND THE CUBIC FEET.

Inches in a cubic foot—1728) 8143·0272 Inches as before.

4·7124 Cubic feet.

TO FIND THE POUNDS.

4·7124 Cubic feet as before.
1000 oz. weight of a cubic foot of water.

16) 4712·4000

294·525 lbs. weight.

A Table showing the weight, wine gallons, and cubic feet of water contained in six feet of pump from four to twenty inches in diameter.

Diameter of Pump.	Weight.	Wine Measure.			Cubic eet.	Diameter of Pump.	Weight.	Wine Measure.			Cubic Feet.
ins.	lbs. dec.	gal.	qts.	pts.	ft. dec.	ins.	lbs. dec.	gal.	qts.	pts.	ft. dec.
4	32·75	3	3	1	·522	12¼	306·95	36	2	1	4·910
4¼	36·95	4	1	1	·591	12½	319·60	38	1	0	5·113
4½	41·42	4	3	1½	·662	12¾	332·51	39	2	1	5·319
4¾	46·15	5	2	0	·738	13	345·68	41	1	1	5·530
5	51·14	6	0	1	·818	13¼	359·10	42	3	1	5·745
5¼	56·38	6	3	0	·902	13½	372·78	44	2	1	5·960
5½	61·87	7	1	1½	·989	13¾	386·72	46	0	1	6·187
5¾	67·63	8	0	0½	1·082	14	400·90	48	0	0	6·414
6	73·63	8	3	0	1·178	14¼	415·35	49	2	1	6·645
6¼	79·90	9	2	0	1·278	14½	430·00	51	1	1	6·880
6½	86·42	10	1	0	1·382	14¾	445.00	53	0	1	7·119
6¾	93·20	11	0	0	1·491	15	460·23	55	0	1	7·363
7	100·22	12	0	0	1·603	15¼	475·69	56	3	1	7.610
7¼	107·51	12	3	0	1·720	15½	491.42	58	3	0	7·862
7½	115·00	13	3	0	1·840	15¾	507·40	60	2	1	8·117
7¾	122·85	14	2	1	1·965	16	523·63	62	2	1	8·379
8	130·90	15	2	1	2·094	16¼	540.13	64	2	1	8·641
8¼	139·22	16	2	1	2·227	16½	556·87	66	2	1	8·909
8½	147·78	17	2	1	2·354	16¾	573·88	68	2	1	9·181
8¾	156·60	18	2	1	2·505	17	591·13	70	3	0	9·457
9	165·68	19	3	0	2·650	17¼	608·65	72	3	0	9·739
9¼	175·00	20	3	1	2·800	17½	626·42	75	0	0	10·022
9½	184·60	22	0	0	2·953	17¾	644·67	77	0	1	10·310
9¾	194·45	23	1	0	3·110	18	662·73	79	1	0	10·602
10	204·54	24	1	1	3·272	18¼	681·26	81	2	0	10.899
10¼	214·90	25	2	1	3·438	18½	700·00	83	3	0	11·142
10½	225·51	27	0	0	8·607	18¾	719·10	86	0	1	11·504
10¾	236·37	28	1	0	3·781	19	738·40	88	1	1	11·813
11	247·50	29	2	1	3·959	19¼	757·96	90	3	0	12·126
11¼	258·87	30	3	1	4·141	19½	777·78	93	0	1	12·443
11½	270·51	32	1	1	4·827	19¾	797·85	95	2	0	12,764
11¾	280·40	33	2	1	4·518	20	818·18	97	3	1	18·090
12	294·53	35	1	0	4·712						

HORSE POWER OF CORNISH STEAM PUMPING ENGINES.

THE following table has been compiled with the object of furnishing an approximate value of the Power in Horses rendered by Cornish Pumping Engines having Cylinders from Fifteen to one hundred inches diameter. The elements employed for the calculations are those most usual with Cornish engineers; and the effective Horse-power per stroke is given, that the inquirer may ascertain the total value of Horse-power resulting from working any given number of strokes per minute. The Steam in most of the Cornish Pumping Engines, is only permitted to act on one side of the Piston; hence such mode of working is technically termed "single acting." Recently, however, it has been considered that equal economy is obtained by introducing the steam on both sides of the Piston, and a few Engines are in operation on this principle. The Horse-power of such (double-acting) engines may be found by doubling the results given in the Table.

Horse-power, Load in Pounds, and Speed per Minute of Cornish "Single Acting" Expansive Steam Pumpi
Inch. Temperature 251·6°. Full Pressure of Steam ½ of

Diameter of Cylinder.	Length of Stroke in Cylinder.	Area of Cylinder.	Load in pounds, less 1-5th, for Friction.	Strokes per Minute.		Speed per Minute in Feet.		Horse Power.		Effec Hors Power Stro
				Economical Working.	Safe Working.	Economical Working.	Safe Working.	Economical Working	Safe Working.	
Ins.	Feet.	Inches.	Pounds			Feet.	Feet.	Horses.	Horses.	Hors
15	8	176·71	2,516	5	14	80	224	3·04	8·53	·610
16	8	201·06	2,863	5	14	80	224	3·47	9 71	·694
17	8	226·98	3,232	5	14	80	224	3·91	10·96	·783
18	8	254·46	3,623	5	14	80	224	4·39	12 29	·878
19	8	283·52	4,037	5	14	80	224	4·89	13 70	·978
20	9	314·16	4,473	4½	12	81	216	5·48	14·63	1·219
21	9	346·36	4,932	4½	12	81	216	6.05	16·14	1·345
22	9	380·13	5,413	4½	12	81	216	6·62	17·71	1·476
23	9	415·47	5,916	4½	12	81	216	7·26	19·36	1·613
24	9	452·39	6,442	4½	12	81	216	7·90	21·08	1·756
25	9·5	490·87	6,989	4½	10½	85½	200	9·05	21·17	2·012
26	9·5	530·93	7,560	4½	10½	85	200	9·79	22·90	2·176
27	9·5	572·55	8,153	4½	10½	85½	200	10·56	24·70	2·347
28	9·5	615 75	8,768	4½	10½	85½	200	11·35	26·57	2·524
29	9·5	660·52	9,405	4½	10½	85½	200	12 18	28.50	2·707
30	10	706·86	10,065	4	10	80	200	12·20	30·50	3·050
31	10	754 76	10,747	4	10	80	200	13·02	32·56	3·256
32	10	804·24	11,452	4	10	80	200	13·88	34·70	3·470
33	10	855·30	12,179	4	10	80	200	14·76	36.90	3·690
34	10	907·92	12,928	4	10	80	200	15·67	39·17	3·917
35	10	962·11	13,700	4	10	80	200	16·60	41·51	4·151
36	10	1017·8	14,492	4	10	80	200	17·56	43·91	4·391
37	10	1075·2	15,310	4	10	80	200	18·55	46·39	4·639
38	10	1134·1	16,148	4	10	80	200	19·57	48·93	4·893
39	10	1194·5	17,009	4	10	80	200	20·61	51·54	5·154
40	10	1256·5	17,894	4	10	80	200	21·68	54·22	5·420
41	10	1320·2	18,799	4	10	80	200	22·78	56·96	5·696
42	10	1385·4	19,728	4	10	80	200	23·91	59 78	5·978
43	10	1452·2	20,679	4	10	80	200	25·06	62·66	6·266
44	10	1520·5	21,652	4	10	80	200	26·24	65·61	6·561
45	10	1590·4	22,647	4	10	80	200	27·45	68·62	6·862
46	10	1661 9	23,664	4	10	80	200	28·68	71·71	7·171
47	10	1734·9	24,705	4	10	80	200	29·94	74·86	7·486
48	10	1809·5	25,768	4	10	80	200	31·23	78·08	7·808
49	10	1885·7	26,852	4	10	80	200	32·54	81·37	8·137
50	10	1963·5	27,956	4	10	80	200	33·88	84·71	8·471
51	10	2042·8	29,089	4	10	80	200	35·25	88·14	8·814
52	10	2123·7	30,240	4	10	80	200	36 65	91·63	9·163
53	10	2206·1	31,414	4	10	80	200	38·07	95·19	9·519
54	10	2290·2	32,612	4	10	80	200	39·52	98·82	9·882
55	10	2375·8	83,831	4	10	80	200	41·00	102.51	10·251
56	10	2463·0	35,072	4	10	80	200	42·50	106·27	10·627
57	10	2551·7	36,336	4	10	80	200	44·04	110·10	11·010
58	10	2642·0	37,620	4	10	80	200	45·60	114·00	11·400
59	10	2733 9	38,930	4	10	80	200	47·18	117·97	11·797
60	10·5	2827·4	40,260	4	9½	84	200	51·24	122·00	12·810
61	10·5	2922·4	41,614	4	9½	84	200	52·96	126·10	13·240
62	10·5	3019·0	42,988	4	9½	84	200	54·71	130 26	13·678
63	10·5	3117·2	44,388	4	9½	84	200	56·49	184·50	14·123

having Cylinders from 15 *inches to* 100 *inches diameter. Initial Pressure of Steam,* 30 *lbs. per Square*
Pressure of Steam 17·8 *lbs. less* 1·5*th friction* 14·24 *lbs.*

Length of stroke in Cylinder.	Area of Cylinder.	Load in pounds, less 1-5th, for Friction.	Strokes per Minute.		Speed per Minute in Feet.		Horse Power.		Effective Horse Power per Stroke.
			Economical. Working.	Safe Working.	Economical Working.	Safe Working.	Economical. Working.	Safe Working.	
Feet.	Inches.	Pounds.			Feet.	Feet.	Horses.	Horses.	Horses.
10.5	3216.9	45,808	4	9½	84	200	58·30	138·81	14·575
10.5	3318.3	47,252	4	9½	84	200	60·13	143·18	15·034
10.5	3421.2	48,716	4	9½	84	200	62·00	147·62	15·500
10.5	3525.6	50,204	4	9½	84	200	63·89	152·13	15·974
10.5	3631.6	51,712	4	9½	84	200	65·81	156·70	16·453
10·5	3739.2	53,246	4	9½	84	200	67·76	161·35	16·941
11	3848.4	54,800	4	9	88	198	73·06	164·40	18·266
11	3959.2	56,379	4	9	88	198	75·17	169·13	18·793
11	4071.5	57,978	4	9	88	198	77· 0	173·93	19·326
11	4185.3	59,598	4	9	88	198	79·46	178·79	19·866
11	4300.8	61,240	4	9	88	198	81·65	183·72	20·413
11	4417.8	62,909	4	9	88	198	83·87	188·72	20·969
11	4536.4	64,592	4	9	88	198	86·12	193·77	21·530
11	4656.6	66,310	4	9	88	198	88·41	198·93	22·103
11	4778.3	68,036	4	9	88	198	90·71	204·10	22·670
11	4901.6	69,798	4	9	88	198	93·06	209·39	23·266
11.5	5026.5	71,578	4	8½	92	196	99·77	212·56	24·943
11.5	5153.0	73,378	4	8½	92	196	102·28	217·91	25,571
11.5	5281.0	75,201	4	8½	92	196	104·82	223·32	26·206
11.5	5410.6	77,046	4	8½	92	196	107·39	228·80	26·849
11.5	5541.7	78,913	4	8½	92	196	110·00	234·04	27·499
12	5674.5	80,804	4	8	96	192	117·53	235·06	29·383
12	5808.8	82,717	4	8	96	192	120·31	240·63	30·078
12	5944.6	84,651	4	8	96	192	123·12	246·25	30·782
12	6082.1	86,609	4	8	96	192	125·97	251·95	31·494
12	6221.1	88,588	4	8	96	192	128·85	257·71	32·213
12	6361.7	90,590	4	8	96	192	131·76	263·53	32·941
12	6503.8	92,614	4	8	96	192	134·71	269·42	33·677
12	6647.6	94,661	4	8	96	192	137·68	275·37	34·422
12	6792.9	96,730	4	8	96	192	140·69	281·39	35·174
12	6939.7	98,821	4	8	96	192	143·73	287·47	35·935
12	7088.2	100,925	4	8	96	192	146·80	293·60	36·700
12	7238.2	103,071	4	8	96	192	149·92	299·84	37·480
12	7389·8	105,230	4	8	96	192	153·06	306·12	38·265
12	7542.9	107,410	4	8	96	192	156·23	312·46	39·058
12	7697.7	109,615	4	8	96	192	159·44	318·88	39·860
12	7854.0	111,840	4	8	96	192	162·67	325·35	40·669

A TREATISE

ON THE QUALITY, MANUFACTURE, AND CHOICE OF CORDAGE, FOR MINING PURPOSES, WITH RULES AND TABLES FOR THE WEIGHT AND NUMBER OF THREADS CONTAINED IN ANY SIZE ROPE.

It is certainly very desirable, if not absolutely necessary, that every person who is intrusted with the management of a mine should possess some means of obtaining, with a degree of certainty, the quality and weight of the ropes he may have occasion to use; otherwise the lives and property intrusted to his care will be continually placed in jeopardy, and his employers be always subject to impositions respecting the charge; because in many cases (from the magnitude of the material) it cannot be weighed, and therefore its weight can only be ascertained by computation; consequently, if the agent is ignorant of the matter, the right of the adventurers will solely depend on the truth of the manufacturer's calculation.

The following tables will enable the agent to find the weight of any rope, and the ensuing remarks will help his judgment respecting the quality thereof; being far the most important part of the subject.

There are various methods of discovering the quality of hemp; but as miners have seldom an opportunity of inspecting the article in this stage of preparation, we shall pass on, and show how it may be proved after its having been completely manufactured.

The first thing that commands our particular attention is, the size of the yarn or thread of which the rope is composed. There is a certain gauge or standard for this, known among ropemakers by the terms, sixteens, eighteens, twenties, &c., which means 16, 18, or 20 yarns in the strand, or third part of a rope 3 inches in circumference. The following table shows the weight of the different sizes of yarn before it has gone through the operation of tarring.

Size.	Length.	Weight	
		lbs.	*oz.*
25	170 fathoms.	2	13
20		3	8
18		3	15
16		4	6
15		4	10

Now the true standard size for shroud-laid rope is *twenties*,* and it is of consequence that agents should give their orders accordingly, and afterwards be assured that their ropes have really been made with yarns of this gauge.

In order to prove this, first, girt the circumference of the rope, then count the yarns in the strand, and, lastly, refer to the table (page 403), and note if the number corresponds with that standing in the proper column, opposite the dimensions of the rope.

Manufacturers have many inducements for spinning their yarn large. First, it is less expensive, for it requires no more time to spin a large yarn than to spin a small one, and 16 or 17 yarns (in their way) will answer the end of twenty. Secondly, in large yarns, inferior or refuse hemp can be spun, which cannot be done in yarns of a smaller size; and this consideration, if there was no other, should cause the agent to be exceedingly particular in having his rope made of standard yarns; and let it be remarked, that although a rope made of sixteens or eighteens will be nearly equal in weight to another made of twenties, yet by no means will it be equal in strength, even if made of the very same kind, or indeed of superior hemp. This is too plain a truth to need any illustration: for though it may be argued that what is wanting in number is made up in bulk, yet it will support an equal weight no more, in proportion, than a body of raw hemp the size of a cable will be as strong as the cable itself.

By inspecting the table (page 403), it will be seen that the strand of a 16-inch capstan-rope made of twenties contains 569 yarns, but if made of sixteens, only 455 yarns; making a difference in the whole rope of 342 yarns.

---

* Of which it is shown in the preceding table that 170 fathoms weigh only 3 lbs. 8 oz., or 3½lbs.

We shall now give a plain and expeditious, though infallible, method, of proving the quality of hemp and yarn, viz., from the end, or *fag*, of the rope cut several of the yarns in fathom lengths, each of these (standard size) should suspend, or bear up separately, 70 pounds weight at the least.

Regard must next be paid to the last part of the manufacture, called the *lay*, or twist, of the rope; and this should undergo a strict examination, as much depends on the skill and attention of the manufacturer in this part of the process; for it is very possible that the best materials may be used, the yarn spun of the proper size, and with the greatest care, and yet the rope be very defective, and by no means fit to be depended on. This may be easily discovered when the rope is laid in a straight line; then, if either of the strands is observed to mount or fall,* that is, rise above or sink beneath the others, in any degree, the rope has been *crippled*, or inevitably spoiled; for if the former case, of one strand rising, in the event of trial, that strand will be found to bear little or none of the weight, when the other two will break; and in the latter case, of one strand sinking, that strand will break before the other two have been brought to the strain, or have borne any considerable part of the weight.

These great defects in cordage are too often to be found, and almost as often pass unobserved; but they may always be detected by a close inspection, and thereby many of the serious injuries and fatal accidents which so often take place in mining, be happily prevented.

---

* This fault or defect is known among ropemakers by the term "pinch," and as the remedy occasions a great deal of trouble and delay, it is too often suffered to pass, especially as few persons are able to detect it, or are aware of its injurious tendency.

There are many casual occurrences whereby ropes are exposed to injuries in mines, out of the common course of working. We may notice an instance or two, viz., inattention or ignorance in taking them from the coil when new; they should always be taken out the contrary way from which they were coiled in; that is, if a capstan rope is coiled into a wagon, the uppermost end should be put down and drawn from the under part of the carriage: also, in small cordage, the inward extremity of the rope should be taken and drawn through the aperture of the reel. The general disproportion of capstan gear in mines has a most destructive effect on the ropes; the sheaves or *pulleys*, as well as the *barrel*, of the capstan being considerably too small; indeed there is still room for much improvement in this part of mining machinery.

We shall close these observations after remarking, that as nearly all cordage used in mining is much exposed to the alternate influence of sun and moisture, which tends greatly to accelerate its decay, it ought by all means to contain a greater quantity of tar than is generally used. The common rule is 1 to 5½, or 1 to 6; but the proportion of 1 to 4^1, or 1 to 5, would be much better: but we recommend this increase for standing ropes only, such as capstan-ropes, &c.; as from the comparative unfrequency of their use, and the length of time they endure, are equally liable to injury from mould and decay, as from strain and friction.

The common practice of tarring the surface of the rope after it has been manufactured is of very little service: the way we recommend is, by reducing the ordinary weight suspended to the lever, during the process of tarring the yarn in the manufactory, when it is drawn in a body from the heated coppers through the knipper, whereby the tar being lodged in the internal part of the rope cannot fail of preserving it under all circumstances.

The following rules, examples, and tables will be found plain, convenient and correct.

TO FIND THE NUMBER OF THREADS IN A SHROUD-LAID ROPE.*

Rule.—State the question as in direct proportion, square the first and third terms, multiply the second and third terms together, and divide the product by the first.

EXAMPLE.

How many standard yarns, or threads, are there in a 14-inch capstan rope?

---

* The term "shroud-laid" is used to distinguish a rope of three strands or parts from another of nine strands, which is termed "cable-laid." The latter may be said to be 3 shroud-laid ropes twisted together. It is seldom that any other but three-strand ropes are used in mines.

```
     in.  yarns.   in.
  As 3  :  20  ::  14
     3             14
     —             —
     9             56
                  14
                  ——
                  196
                   20
                 ————
              9) 3920
              ———————
   Answer     435 threads in the strand.
                3
              ————
          or 1305 threads in the rope.
              ————
```

EXAMPLE.

How many standard yarns are there in a 9½ inch rope?

```
     in.  yarns.  in.
  As 3  :  20  :: 9·5
     3             9·5
     —             ———
     9             475
                  855
                  ————
                  90·25
                     20
                 ———————
              9) 1805·00
              ——————————
   Answer     200· threads in the strand.
                3
              ———
              600 threads in the rope.
              ———
```

TO FIND THE WEIGHT OF SHROUD-LAID ROPES.

Rule.—State the question and square the numbers as in the last example.

EXAMPLE.

If 1 cwt. of 3-inch rope measures 54 fathoms*, what will be the length of a cwt. of a 12-inch rope.

```
     in.        fath.          in.
  As 3    :      54      ::    12
     3            9            12
     —          ————           ———
     9     144) 486 (3·375     144
                432      6
                ————  —————
                540   2·250
                432      12
                ————  —————
                1080  3·000
                1008
                ————
                 720
                 720
                ————

                          fath. ft. in.
                   Answer   3    2   3
```

---

* The length of standard yarn to a lb. is 48 fath. 2 ft. 4·3 in. after it has been tarred, and 54 fathoms of 3-inch rope are exactly 1 cwt. By this rule the following tables have been constructed. It must be recollected that this computation is made, estimating the proportion of tar 1 to 5½ only.

EXAMPLE.

If 100 fathoms of 3-inch rope weighs 1 cwt. 3 qrs. 11·3 lbs., what will be the weight of a 15-inch rope the same length?

```
    in.  cwt. qrs. lbs.
  As 3  :  1   3   11·3  : :  15
     3     4                  15
     —     —                  —
     9     7                  75
          28                 15
        ——————               ———
        207·3                225
          225
     ——————————
  9) 46642·5
     ——————————
112)  5182  (46
      448
      ———
       702
       672
       ———
        30
       ———

                       cwt. qr. lbs.
               Answer  46   1   2
```

TO FIND THE WEIGHT OF ROPES BEING 120 FATHOMS IN LENGTH.

Rule.—Divide the circumference of the rope by 2, and square the remainder.*

EXAMPLE.

What is the weight of a 12-inch rope 120 fathoms long?

```
        2) 12
           —
            6
            6
           —
Answer     36 cwt.
           —
```

EXAMPLE.

What is the weight of a 14½-inch rope 120 fathoms long?

```
2)  14·5
  ————————
      7·25
      7·25
  ————————
   52·5625
         4
  ————————
    2·2500
     28
    —————
    200
    50
    ————————
    7·0000
    ————————
                    cwt. qrs. lbs.
            Answer  52    2    7
```

---

* This rule is not perfectly accurate, but may be useful in affording a clue for finding the approximate weight of ropes, especially if the circumference is in even numbers, it may then be used mentally, or by the mind only.

TABLE I.

SHOWING THE NUMBER OF THREADS IN THE STRAND OF A SHROUD-LAID ROPE.

Size of Rope.	Size of Yarn. Sixteens.	Size of Yarn. Twenties.	Size of Rope.	Size of Yarn. Sixteens.	Size of Yarn. Twenties.
Inches.	Number.	Number.	Inches.	Number.	Number.
2	7	9	9½	160	200
2½	10	14	10	177	222
3	16	20	10½	196	245
3½	21	27	11	215	268
4	28	35	11½	235	293
4½	36	45	12	256	320
5	44	55	12½	278	347
5½	53	67	13	300	375
6	64	80	13½	324	405
6½	75	93	14	348	435
7	87	109	14½	374	467
7½	100	125	15	400	500
8	113	142	15½	427	533
8½	128	160	16	455	569
9	144	180	16½	484	605

The difference of the number of threads in the whole rope will be found by subtracting the numbers standing under "sixteens" from those under "twenties," and multiply the remainder by 8. (Thus 256—320=64×8=192.) Therefore it appears that a 12-inch rope made of "twenties" contains 192 threads more than another, of the same circumference, made of "sixteens."

TABLE II.

SHOWING THE LENGTH OF SHROUD-LAID ROPES TO A CWT. FROM 1 TO 16 INCHES IN CIRCUMFERENCE.

Size of Rope.	Fath.	Feet.	Inches.	Size of Rope.	Fath.	Feet.	Inches.
Inches.				Inches.			
1	486	0	0·0	9	6	0	0
1½	216	0	0·0	9½	5	2	3·7
2	121	3	0·0	10	4	5	1·9
2½	77	4	6·7	10½	4	2	5·4
3	54	0	0·0	11	4	0	1·2
3½	39	4	0·0	11½	3	4	0·9
4	30	2	3·0	12	3	2	3
4½	24	0	0·0	12½	3	0	7·9
5	19	2	7·7	13	2	5	3·1
5½	16	0	4·3	13½	2	3	11·5
6	13	3	0·0	14	2	2	10·4
6½	11	3	0·0	14½	2	1	10·4
7	9	5	6·2	15	2	0	11·5
7½	8	3	10·0	15½	2	0	1·4
8	7	3	6·7	16	1	5	4·6
8½	6	4	4·3	16½	1	4	8·5

The exact weight of a rope of any length may be found by the above table and the rule of proportion.

EXAMPLE.

Required the weight of 25 fathoms of 14-inch rope?

```
      fath. ft. in.     cwt.   fath.
   As  2    2   10·4  :  1  ::  25
       6                         6
       —                        ——
      14                       150
      12                        12
     ————                      ————
     178·4               178·4) 1800 (10·09
                                        4
                                        —
                                       86
          cwt. qrs. lbs.               28
   Answer 10    0   10                ————
                                      10·08
                                      ————
```

TABLE III.

SHOWING THE WEIGHT OF SHROUD-LAID ROPES 100 FATHOMS IN LENGTH.

Size of Rope.	Cwt.	Qrs.	Lbs.
Inches.			
3	1	3	11·3
4	3	1	4
5	5	0	15
6	7	1	16
7	10	0	9
8	13	0	17
9	16	2	15
10	20	2	4
11	24	3	11
12	29	2	14
13	24	3	3
14	40	1	12
15	46	1	2
16	52	2	22

NOTE.—The weight of any length of rope may be found by the above table and the rule of practice.

EXAMPLE.

What is the weight of 47 fathoms of 11-inch rope?

```
                cwt. qrs. lbs.
   | 25 | 1/4  | 24   3   11
                ——————————————
   |    | 1/5  |  6   0   24
   | 20 |      |  4   3   24
   |  2 | 1/10 |  0   1   27
                ——————————————
        Answer   11   2   19
                ——————————————
```

The weight and circumference of any rope being given, the length may be found by the foregoing table and the common rule of proportion, or by decimals.

EXAMPLE.

What is the length of 7 cwt. 3 qrs. 14 lbs. of 7 inch rope?

```
   cwt. qrs. lbs.  fath.   cwt. qrs. lbs.
As 10   0    7  :  100  ::  7   3    14
    4                       4
   --                      --
   40                      31
    4                       4
  ---                     ---
  161                     126
                            100
                          -----
                     161) 12600
                          ------
                            78·26
                            -----
```

OTHERWISE.

```
     cwt.        fath.      cwt.
As 10·0625   :   100   ::  7·875
                              100
                        ---------
               10·0625)787·500
                        ---------
                          78·26
                              6
                          -----
                           1·56
                             12
       fath. ft. in.       ----
Answer  78   1   6         6·72
                           ----
```

Or the length of any rope may be known by the 2d table and the rule of practice.

EXAMPLE.

What is the length of 16 cwt. 2 qrs. 21 lbs. of a 10¼ inch rope?

```
             fath. ft.  in.
      | ¼ |   4    2   5·4 to a cwt. by the table.
      |   |                8
      |   |  ---------------
      |   |  35    1   7·2
      |   |                2
      |   |  ---------------
      |   |  70    3   2·4
      | ½ |   2    1   2·7
      | ¼ |   0    3   3·6
      |   |   0    1   7·8
             ---------------
Answer       73    3   4·5
             ===============
```

WIRE ROPE—ITS ADAPTABILITY TO MINE SERVICE.

WIRE rope has nearly superseded hemp in the mining service, and as it is an object to the miner to know the best means by which to hoist or transport minerals, I will lay before the reader some remarks collated from the best practical authorities. The late Frederick Overman, in his work on Mining and Metallurgy, has some excellent remarks upon this point:

"Chains have been used, but they are found unsafe, heavy and expensive, and are most generally abandoned. The question is now between iron wire rope and hemp rope. In general one pound of wire rope is equal in strength to one pound of good hemp rope; it is in most cases three times as strong, but there is no necessity of claiming more than pound for pound. One pound of hemp rope will cost from 15 to 20 cents, and one pound of wire rope from 12 to 15 cents; here is, therefore, the advantage in favor of the wire rope. Hemp rope is very unequal in quality; ropes of one and the same size may be the one twice as strong as the other. This cannot happen in wire ropes; the one quality of wire may be inferior in strength to another, but there cannot be so much fluctuation as is frequently found between hemp ropes. There is another advantage of the wire rope. Hemp ropes are heavy, particularly when working in water and mud; they require more room than a wire rope, and of course the machinery, particularly the drum, must be more capacious. As regards durability, we may state that, generally speaking, a wire rope will outlast six hemp ones, under common circumstances; but there are exceptions, in which the hemp rope outlasts the wire rope. In coal mines, or mines in which pyrites is decomposed, a large quantity of sulphuric acid is produced, which mingles with the water; this sulphuric acid is generally combined with some solid matter, such as clay, or oxide of iron, and forms with these basic salts. These combinations of the acids do not hinder its corrosive action on iron."

Wire rope is as pliable as new *hemp rope* of the same strength, and will run on the same size sheaves or pullies, but the greater the diameter of the sheaves the longer the rope will wear. Short bends should be avoided. From experience it would appear that the wear increases with the speed, and that it is better to increase the load rather than the speed.

The results of a set of experimental tests recently instituted in England, to ascertain the comparative strength of wire, hempen and Manilla ropes, show conclusively the superiority of wire ropes.

The following are the size and materials of the samples subjected to experiment, with the results:

	T.	C.
3¾ inch galvanized wire rope, broke at	20	15
3¾ inch Manilla hemp	5	17
3¾ inch Russian hemp	4	15
3¼ inch galvanized wire rope	16	10
2¼ inch galvanized wire rope	8	10

There were also some experiments made with soft and hard wire rope, with results greatly in favor of the hard wire. The hard wire was found to bear 60 per cent. greater strain than the soft. Both wires were the same, the one remaining precisely as when drawn, the other having been annealed. The annealed is most pliable for splicing; but being found so much weaker, the decision was, of course, in favor of the hard wire.

The testing of the hemp ropes proving the strength of Manilla to be so far superior to Russian hemp, will be received by many with surprise, as a converse opinion is generally entertained. The straining tests show the immense superiority of wire rope over that made of the best fibrous material.

The following table exhibits the results of tests made to ascertain the ultimate strength of Mr. Roebling's Patent Wire Rope manufactured at Trenton, N. J., also the size of rope of equivalent strength made from hemp. The results given in the table are approximated at 12 per cent. less than the actual breaking strength:

FINE WIRE.

Wt. per Foot in Pounds.	Number.	Circumference in Inches.	Price per Foot in Cents.	Ultimate strength in Tons of 2000 lbs.	Circumference of Hemp Rope of equivalent strength in inches.
7.43	1	6.62	104	74.00	15½
6.5	2	6.20	91	65.00	14½
5.4	3	5.44	79	54.00	13
4.36	4	4.90	68	43.60	12
3.5	5	4.50	56	35.00	10¾
2.72	6	3.91	45	27.20	9½
2.02	7	3.36	35	20.20	8
1.6	8	2.98	30	16.00	7
1.14	9	2.56	24	11.40	6
.864	10	2.45	21	8.64	5

COARSE WIRE.

Wt. per Foot in Pounds.	Number.	Circumference in Inches.	Price per Foot in Cents.	Ultimate strength in Tons of 2000 lbs.	Circumference of Hemp Rope of equivalent strength in inches.
3.6	11	4.45	47	36.00	10¾
3.	12	4.00	40	30.00	10
2.5	13	3.63	36	25.00	9½
2.	14	3.26	30	20.00	8¼
1.6	15	2.98	25	16.00	7¼
1.23	16	2.68	20	12.30	6¼
.88	17	2.40	15	8.80	5½
.76	18	2.12	13	7.60	5.00
.59	19	1.90	11	5.80	4.75
.43	20	1.63	9	4.09	4.00

Experience demonstrates it is good economy in proportioning sheaves and drums, to give them 12 inches in diameter for one quarter inch diameter of rope. Example, one inch diameter of rope 48 inches diameter of drum. The working load should not be over one quarter the ultimate strength given in table.

Small ropes will work better than large. The Delaware and Hudson Canal Company tried large wire ropes on their planes at Carbondale some years ago, but they only lasted a few months; they are now using ropes less than an inch in diameter, and find them to work well. To guard against rust, stationary rope should be oiled once a year at least with linseed oil, or coated with a durable paint. Running rope while in use requires no protection. On inclined planes and in mines they will be found not only safer but more economical. In conclusion of this subject, a few remarks relative to its manufacture, which, like the production of many other similarly valuable commodities, is simple, yet combining with much ingenuity, and a great deal of well-arranged machinery, will be appropriate here. At present there are but two establishments in the United States for the manufacture of wire rope, Mr. Roebling's, at Trenton, N. J., and Mr. Fisher Hazard's, at Mauch Chunk, Carbon county, Pa.; the products of either establishment are well recommended by practical men, and have stood severe tests.

In the first place, the *iron* from which the wire is made, should be of the very best quality.

The wires being prepared, next comes the laying from them of the strands, and finally, the laying of the strands into rope.

Each strand usually consists of 3, 7, or 19 wires, the ropes having 9.49 or 133 wires.

The two most important considerations to be effected in laying up the rope are, that when the rope is made and subjected to its duty, that the tension of each wire shall be equal, and that there shall no twist take place in the wires while being laid into strands, nor in the strands while being laid into the rope.

The rope when manufactured or in use should never be coiled, but wound around a drum or wheel. The rope can be easily spliced; in joining ends together, what is termed the long splice, should always be used. To the ends, when required, can be attached a socket, hook-clevis, turn-buckle, or any similar appendage, in a perfectly secure and safe manner.

GASES AND VENTILATION OF MINES.

IT appears that the volume of air inhaled by a man is about 19 cubic metres in 24 hours, or 792 litres an hour. The volume of carbonic acid gas exhaled is about one-thirty-third part of the volume of the air inspired; consequently a man exhales 570 litres per day, or 24 litres per hour of carbonic acid gas; and a litre being 0·264 gallons, the quantity of air inspired by a man is 209 gallons hourly, and the quantity of carbonic acid gas expired 6·336 gallons per hour.—(*Annales des Mines, first Series, Vol.* 10, *p.* 45.)

According to Sir Humphry Davy and Dr. Henderson, about 5 cubic inches of azote are consumed every minute by an ordinary sized man. Allen and Pepys say that azote is given out by the lungs; and Ellis has labored to show that in respiration the natural azote of the atmosphere is untouched in quantity and unchanged in quality. The combustion of candles or lamps absorbs a quantity of oxygen, which depends on the nature and weight of the substance burnt in a given time. There are at the same time produced carbonic acid gas and watery vapor.

The combustion of a lamp of the largest size employed in mines consumes less oxygen than the respiration of one workman. The oxygen of the air is also absorbed by the chemical decomposition of many substances which are ordinarily found in mines. Thus under the compound influence of air and moisture, sulphurets are transformed into sulphate, as in the case of iron pyrites, which we find transformed into sulphate of iron; and we know that vegetable and animal matters in the same circumstances undergo a putrid fermentation, in which the oxygen of the air disappears, combining with some of the elementary principles of these substances—the products being dissipated into the surrounding air. These are chiefly carbonic acid gas, carbonic oxide (?), gaseous compounds of carbon and hydrogen, azote and ammonia. These gases are mixed with other substances which chemical analysis has been unable to isolate. They have usually a sickly odor, and exercise over people who respire them an action in the highest degree deleterious: they have received the name of Miasmata. The gases due to the chemical decomposition of certain substances are principally those which are formed by the deflagration of the powder employed in the works of the mines—varied most probably by the charge of powder, and perhaps also as it is more or less damp, and the combustion consequently more or less perfect, they form a composition of carbonic acid, azote, oxide of carbon, watery vapor, carburetted hydrogen, and a little sulphuretted hydrogen. The solid products of the detonation, which are composed of unburnt powder, sulphate of potash, and sulphuret of potassium, are projected in very minute particles into the surrounding air, which is obscured by them. The fumes of powder, blasting powder especially, have a disagreeable odor, and irritate powerfully the organs of respiration; consequently it is indispensable to expel them by the prompt renewal of the air in the place where the blasting has taken place.

The gases met with in mines which when insufficiently diluted with atmospheric air are productive of deleterious effects upon the workmen, or capable of forming with it an explosive compound, are as follows:

1. *Carbonic acid*, called also stythe or black-damp.
2. *Bihydruret of carbon*, called also fire-damp, mixed occasionally with *hydruret of carbon, or olefiant gas*, according to some European authorities.
3. *Sulphuretted hydrogen*, rarely.
4. *Oxide of carbon?*

1. CARBONIC ACID consists of two atoms of oxygen and one atom of carbon. Its specific gravity, as compared with air, is 1·524: weight of 100 cubic inches 46·576 grains. Water absorbs nearly its own volume of this gas: caustic alkalies and alkaline earths absorb it very rapidly. It is unfit for the support of combustion and respiration. Atmospheric air, mixed with one-tenth

of this gas, becomes unfit for the support of combustion, and lights burn badly in an atmosphere containing from 5 to 6 per cent.: air containing about 8 per cent. of carbonic acid cannot be respired without danger. This gas appears to act on persons who respire it in the manner of poisons; and it is necessary, in order to prevent its effect being fatal, that persons asphyxiated by this gas, should remain in it a very short time: when they remove from it, they remain unwell, particularly with violent headache, for some days. Carbonic acid is frequently disengaged in mines from the fissures and cavities of the strata, and is formed, moreover, by the respiration of the workmen and horses, and also by the combustion of lights and deflagration of gunpowder.

On account of its great specific gravity, carbonic acid has a tendency to accumulate in great quantity in the low parts of all excavations, notwithstanding the general property possessed by gases, of intermixing or diffusing themselves throughout each other, when contained in any isolated space.

2. *Hydruret of carbon or firė-damp*, is composed of two atoms of hydrogen and one atom of carbon: its specified gravity is 0·555, and the weight of 100 cubic inches is 16.92 grains; it is insoluble in water, and is not absorbed by alkalies. When mixed with atmospheric air in the proportion of from 1-30th to 1-15th of the total volume, the flame of a candle plunged into the mixture is elongated according as the proportion of inflammable gas approaches 1-15th of the volume.

The flame of the wick is surrounded by a halo of pale blue, which is most perceptible towards the point. The combustion only takes place around the wick, and does not extend to the surrounding mass. When the fire-damp forms 1-14th of the total volume, the inflammation extends throughout the whole gaseous mass, but without loud detonation. The rapidity of the inflammation increases with the proportion of the inflammable gas until it amounts to 1-9th or 1-8th of the total volume: in these latter proportions the mixture is explosive in the highest degree.

If the proportion of fire-damp is increased still further, the mixture becomes less and less explosive; and when the mixture contains more than one-third of the volume of gas, it is no longer inflammable, but any flame immersed in it is, on the contrary, extinguished.

The contact of iron or coal at a red heat is not sufficient to produce the inflammation of fire-damp mixed with air: the presence of flame is necessary.

This, the generally received opinion, ought not to be too confidently relied upon, as is shown by the following experiment. The gas experimented on was passed through a drowned drift, and was conveyed by means of a pipe in the shaft to the surface; it then passed through naphtha into a gasometer, and thence to various burners in the shops and elsewhere.

There was also a cock between the top of the shaft and the naphtha vessel, whence, when opened, the gas issued in its natural form. The first experiment consisted in placing a bolt about two inches in diameter, heated to a cherry red, in contact with the naphthalized gas in the smith's shop.

The gas was immediately inflamed; in a short time, however, the iron, still at a good red heat, ceased to possess the power of exploding the gas. Precisely the same effects were produced when the iron was applied to the gas issuing from the cock between the pit and naphtha vessel.—(*Transactions of the North of England Institute of Mining Engineers, vol.* 1.)

Azote, or carbonic acid, added even in small proportion to an explosive mixture of air and fire-damp, weakens or even prevents explosion; 1-7th of carbonic acid added to a mixture the most explosive, sufficing to render it the contrary. Bihydruret of carbon mixed with atmospheric air can be respired without danger, so long as it constitutes less than one-third of the total volume; beyond this proportion, it causes asphyxia by insufficiency of oxygen.

Fire-damp is disengaged from the mud in marshes and from all stagnant waters, whence it may be easily obtained by stirring up the mud with a stick, and placing an inverted bottle full of water over the bubbles as they arise. In some localities it flows from the fissures of the soil, and gives rise to natural fires, which exist in many places. Borings executed in exploring for rock salt have sometimes produced abundant jets of this gas.

But it is principally found in coal mines, escaping from the cells of this mineral with a slight noise, analogous to that produced by boiling water. It is generally disengaged in the greatest abundance in places which are in the neighborhood of vaults, near which the nature of the coal is altered. There are also in the interior of coal beds cavities, where the gas is pent up under considerable pressure, and from which it escapes suddenly whenever the side of the cavity nearest to the workings is weakened by their approach, so as no longer to be able to withstand the internal pressure.

The following facts have been recorded of the volumes and pressures of gas yielded under circumstances of this nature—(*Report on the Ventilation of Mines and Collieries, by John Phillips, Esq.*, F. R. S. p. 8.) The first was experienced Nov. 13th, 1846: on this occasion, a mass of coal was displaced 8 feet long on one side, 4 feet long on the other, and nearly 6 feet high. This, with the disintegrated or danty coal which slipped from the dyke, must have weighed about 11 tons. A discharge of fire-damp ensued; the two men working the place secured their lamps (one of which had been partially covered with the fall of coal, but continued to burn; the other nearest the issue of gas had been put out), drew down the wick of that which continued to burn, hastened to apprise the other men in the pit, extinguishing the lamps as they proceeded, and finally retired to the shaft.

The extent of airways fouled at the same time contained about 41,681 cubic feet, and in from 15 to 20 minutes after the eruption there were no longer any traces of fire-damp. The air moved in this part of the mine at the rate of 6.24 feet per second, the quantity passing per minute amounting to 10.483 cubic feet. A second discharge of fire-damp took place on the 10th of December, 1846, at a different point of the same slip; in this case the gas came off from the danty coal with a violent noise, like the blowing off of high pressure steam, and fouled the air-courses for an extent of 641 yards in length, with an area of 86,306 cubic feet. The air was circulating at the rate of 5½ feet per second, and the quantity was about 16,000 per minute. After 12 or 15 minutes all appearance of gas had ceased, excpting near the point of issue of the blowers.

According to Sir H. T. de la Beche and Dr. Lyon Playfair, the analyses of fire-damp obtained from several coal mines of the North of England, presented the following results:

	First.	Second.	Third.	Fourth.	Fifth.
Bihydruret of carbon........	92 8	77 5	88 1	86 0	79 7
Nitrogen....................	6 9	26 1	14 2	12 3	14 3
Oxygen......................	0 0	0 0	0 6	0 0	3 0
Carbonic acid...............	0 3	1 3	2 1	1 7	2 0
Hydrogen....................	0 0	0 0	0 0	0 0	3 0
	100 0	104 9	100 0	100 0	102 0

The general result of this examination is, that the only inflammable constituent present in the explosive gas of these collieries is by hydruret of carbon. There is not a trace of olefiant gas, and only in one of the gases analyzed is there any hydrogen.

When bihydruret of carbon cannot be procured from its natural source, it may be obtained artificially by distilling in a coated glass flask at a red heat, the following mixture:

1 part stick potassa,
1 part dried acetate of soda,
1½ part quick lime,

all rubbed to fine powder and well dried.

It is necessary in this place to make some remarks upon the hydruret of carbon, or olefiant gas: it is composed of one atom hydrogen, and one atom of carbon: its specific gravity is 0.972, and the weight of 100 cubic inches 29.646 grains. It burns with a red flame, of which the illuminating power is much greater than that of bihydruret of carbon. A considerable quantity of this gas is contained in that obtained from coal by distillation (or common street gas), as appears from the following analyses by Dr. Henry:

Constituents in Volume.

No.	Specific gravity.	Hydruret of carbon or Olefiant gas.	Bihydruret of carbon or fire-damp.	Carbonic Oxide.	Hydrogen.
1	0 620	12	64 53	7 33	15 84
2	0 630	12	57 49	13 35	17 16
3	0 500	7	55 80	13 95	23 25

Common gas, from its mixture with olefiant and hydrogen gases, is much more inflammable than fire-damp, being easily ignited by iron at a low red heat.

It results from the analyses of Mr. Bischoff, of Bonn, that olefiant gas is mixed with the fire-damp of many coal mines—a circumstance which has led this chemist to conclude that the inflammable gases of coal mines are mixtures in different proportions, according to locality, of fire-damp, olefiant gas, and also of other gases in small quantity.

3. Sulphuretted Hydrogen.—This gas is characterized by the odor of rotten eggs. It is composed of one atom of sulphur

and one atom of hydrogen: its specific gravity is 1.1805, and the weight of 100 cubic inches is 36.008 grains. It is soluble in water, which is capable of absorbing three times its volume of this gas; alkaline solutions absorb it rapidly: chlorine decomposes it by combining with the hydrogen, forming a deposit of sulphur. Mixed with air, it takes fire at the approach of flame, the products of the combustion being water and sulphurous acid.

When present even in small quantity in a gaseous mixture it blackens the white oxide of lead and bismuth, which enables us easily to detect its existence. It is sufficient to expose to the mixture in which it is contained, slips of paper which have been dipped in a solution of acetate of lead and allowed to dry.

It exercises upon the animal economy an influence deleterious in the highest degree: a bird perishes in air containing 1-1500th part of its volume of this gas: the 1800th part is sufficient to kill a moderate sized dog (Thenard). The later researches of M. Parent Duchatelet would, however, seem to show that the poisonous effects of this gas have been somewhat exaggerated, at least in the application of these results to man. He observed that workmen breathed with impunity an atmosphere containing 1-100th part of sulphuretted hydrogen, and he states that he himself respired without serious symptoms ensuing, air which contained 3 per cent.

This gas is formed whenever sulphur in a very comminuted form is brought into contact with hydrogen in a nascent state. Thus it may form in mines where there is a decomposition of iron pyrites. It has been met with in old colliery workings, but its occurrence is rare.

4. OXIDE OF CARBON.—This gas consists of one atom of oxygen and one atom of carbon. Its specific gravity is 0.972; weight of 100 cubic inches 29.64 grains.

According to the recent work of M. Leblanc, oxide of carbon produces upon the animal economy an action more deleterious than that caused by carbonic acid. It burns with a beautiful blue flame, and gives out but little light; when mixed with common air it does not explode like fire-damp, but burns brilliantly: and from this circumstance it appears that a portion of this gas contained in any atmosphere might produce a compound in which a candle might burn brightly, but in which human life must be immediately extinguished; and I am very strongly of opinion that there exist instances of this nature, some fatal accidents having occurred, almost unaccountable excepting under this supposition.

From the properties of the gases above described, we may (excepting oxide of carbon) penetrate without danger into any atmosphere which we find to possess no disagreeable odor, which will not blacken acetate of lead, and in which a safety lamp will burn with facility; but as even under all these circumstances the atmosphere may, from the presence of oxide of carbon, be unfit for respiration, we are led to the one only practically safe conclusion, that we should, under all circumstances, be accompanied by a sufficient circulation of fresh air, the means of obtaining which I propose to treat of in the following order:—

1st. Natural ventilation. 2d. Artificial ventilation, *a* by waterfall, *b* by furnace, *c* by steam, *d* by machinery.

1. NATURAL VENTILATION.

When we have two shafts of unequal depth to the same level underground, we have a circulation of air established, the character of which will be as follows:—It will be remembered that there is a point where the temperature of the earth corresponds with the mean temperature at the surface, and that below this point the temperature increases with the depth. The consequence of this is, that we have a higher mean temperature, and a lighter column of air in the longer shaft than in the shorter one, at all times when the surface temperature is as low as or lower than the mean temperature of the mine. As the temperature of the atmosphere however increases, the difference of heat between the two shafts diminishes, and ventilation becomes gradually more and more feeble, until at length, when the two shafts become equal, it stagnates altogether. It may then happen (especially in pits of small depths) that the ventilation will be reversed, not indeed for any length of time, but only until that which has now become the downcast shall, in its turn, by the introduction of the hot surface atmosphere, again become the warmer of the two.

In pits of great depth, however, where the temperature under ground far exceeds any mean, and even equals that of the hottest summer, natural ventilation may continue uninterrupted and of considerable power. The rationale of the motion of a column of air under such circumstances will be explained shortly.

Natural ventilation, however effectual it may be found in deep mines, having few ramifications, accompanied by freedom from inflammable or noxious gases, is quite inadequate to keeping in a safe and healthy state mines where these gases abound, not only on account of its comparative feebleness, but on account of its liability (especially in mines of moderate depth) to be disarranged by changes of atmospheric temperature. We must, therefore, have in all mines artificial means at hand: in some, not perhaps necessary to be used at all times, but immediately applicable under any circumstances affecting the circulation of air produced by natural causes. This then leads us to the consideration of artificial ventilation.

2. ARTIFICIAL VENTILATION.

a. THE WATERFALL.—This may be effected by allowing a portion of water to fall down the downcast shaft, which produces a very good current of air if the water be in any considerable quantity, and the fall be great.

The effect of a waterfall, consisting of a quantity of water passing through two holes, one inch in diameter each, and flowing sixty-three fathoms, may be judged by the following experiment made at Blackboy Colliery, May 8, 1845. The colliery was at this time ventilated by a nine-feet furnace, and the experiment was made in one of the working districts, previous to and after subdividing the portion of air applied to its ventilation.

1. BEFORE SPLITTING THE AIR.

	Cubic feet.
The quantity passing into the district with the furnace alone was	8,394
After putting on the waterfall it was	11,565
Increase due to waterfall	3,171

2. AFTER SPLITTING THE AIR.

	Cubic feet.
The quantity passing into the district with the furnace alone was	11,313
After putting on the waterfall it was	13,687
Increase due to waterfall	2,374

The reason of this reduced increase will be explained hereafter, when we discuss the important question of resistance.

Although in cases of emergency the waterfall may be applied as a useful ventilating power, yet it is subject to great objection on two accounts; for it occasions the return into the mine of a considerable quantity of water, which is to be again drawn out, and it so produces a dampness in the air which is very injurious to the timber used in the mine, causing its rapid decay. After an explosion, when the furnace is inaccessible, it is a ready way, as causing a circulation of air through the mine; but excepting in extreme cases, or when it is necessary to suspend for repairing the ordinary ventilating power, it is a means of ventilation which cannot be recommended.

b. THE FURNACE.—The system of ventilation usually adopted, consists of a furnace or fire placed near to the bottom of the upcast shaft, for the purpose of rarefying the air contained therein, and should be adopted in the first instance in hot weather, on the failure of the ventilation produced by natural causes.

The theory of the action is as follows:—First, that the velocity of the ventilating current increases with the temperature of the upcast shaft, because the velocity of the current increases with the length of the motive column, which, other things being equal, depends on the temperature of the upcast shaft. The converse of this, although not for the same reason, is also true; viz., that the temperature of the upcast shaft, other things being equal, depends on the velocity of the air current; or, in other words, if by using an addition to the furnace, any mechanical or other means, we increase the quantity of air, we shall find such increase to be in a greater ratio than is due to the mere mechanical agent employed, inasmuch as we shall find a higher mean temperature in the upcast, and the motive column increased in a corresponding degree, owing partly to the fierce combustion of the furnace, and partly to the more rapid travel of the hot air up the shaft, and consequent higher point which it attains before losing its temperature by absorption, radiation upwards, or whatever cause produces that diminution in heat which takes place so rapidly.

Second, the quantity of air depends upon the air channels being shortened and made of as large area as possible.

The shortening of the mine channels may be effected in a great degree by splitting the air, as it is called, or dividing the main current of the downcast shaft into subordinate currents, each having a separate district to ventilate, instead of causing the main current to travel in an undivided state through the whole of the ramifications of the mine, besides the effect of shortening the run of the air, the other requisite, viz. that of enlarging the average area of the air channel is also produced by splitting the air. In splitting the air two points require particular attention.

1. Not to carry the principle too far, otherwise each split will be feeble and inefficient.

2. To have large channels before splitting the air, and also after the divisions have been reunited.

If any district of a mine evolves so large a quantity of fire-damp, that its being mixed with the rest of the return air would raise the whole current to the firing point, the split of air which ventilates such district must of course be taken into the upcast shaft by some other means than by that of the furnace. A drift is therefore driven in fiery mines from one of the returns into the upcast shaft, by means of which any division of air which is of a dangerous character, may be conveyed into it. The point of delivery into the shaft of such a drift, should not be less than 8 fathoms above the furnace to drift end, so as to preclude the possibility of the inflammable gas being ignited by any ascending flame. There are cases in which the whole of the return air must pass into the upcast, without contact with any flame, in which case the furnace must be fed entirely with fresh air from the downcast shaft. In order to regulate the quantity of air which it is desirable to pass through each district, a description of door is required, which should be 6 feet wide by 3 feet 6 inches in height, fixed in a frame and divided vertically into halves, one of which is movable behind the other half, which is fixed. This frame is placed in any single return from the districts where the air has the shortest distance to travel, and is opened sufficiently wide to allow the requisite quantity of air to pass through. There ought to be means provided, by lock or otherwise, of securing the slide in the required position, to prevent any ignorant or mischievous person from altering the proper distribution of the air.

In all fire-damp mines requiring, in consequence, an active ventilation, the necessity of having large air-ways is paramount to every other consideration.

The essentials to produce a good furnace ventilation may be shortly summed up as follows:—

1. Powerful means of heating the air.

2. Length of heated column, which in shallow mines may be

augmented by a tube, or chimney, of the size of the shaft, and erected over it.

3. Short air-courses (equally requisite, whatever be the ventilating power employed).

4. Large areas of air channels (ditto).

It would be superfluous in this place to state the lengths or dimensions which ought to be given to upcast shafts or air-ways; because the circumstances of all mines are so varied, both as regards their extent and the quantity of air they require in order to their being sufficiently ventilated, that no fixed rule would be found applicable to any one mine for any length of time. A few remarks, however, on the construction of furnaces may not be out of place:—The essential of a complete furnace is, that it should possess abundant power of heating, to a high degree, a rapid current of air of large dimensions.

It is an error to suppose that it is necessary, in order to heat the air to a high temperature, that it ought to be forced through the bars of the furnace, for air should be *forced* nowhere. The fact is, that so great is the radiation of heat from the furnace, that when properly constructed and attended to, it is capable of heating many times the quantity of air which usually passes over it, to as high a temperature as that which ordinarily passes into the upcast shaft.

In the construction of ventilating furnaces, the general mistake is to raise the bars too high, which has the effect of contracting the air-way above the fire, and thus produces an injurious effect. The furnace may be placed near the bottom of the shaft, if used exclusively as an upcast, but should be 50 or 60 yards distant from it, if the shaft is used as a winding shaft also, or in cases where gas or dumb-drifts are necessary; the drift from the furnace ought to have an inclination upwards towards the pit of not less than 1 in 6.

c. STEAM.—In the first report of the Society for Preventing Accidents in Coal Mines, written in 1814, by Mr. Buddle, is a drawing and description of a steam ventilator, by which steam is carried down and discharged in a shaft from a boiler placed at the surface. The steam in this was delivered downwards into the upcast shaft, and the ventilation to be produced was entirely dependent upon the temperature arising from the steam. The next attempt at steam ventilation was made in Wales, by Mr.

Stewart, in 1828, but the system was not found to produce the effect required, and consequently abandoned.

The steam blast applied to the locomotive engine, having proved so admirably effective in producing that violent draught of air so essential to its wonderful concentration of power, induced Mr. Gurney to conceive that great benefit would arise from its application in somewhat similar manner to the ventilation of mines; and we find that in July, 1855, before a parliamentary committee, appointed to inquire into the causes of accidents in mines, and in October, 1839, in a letter addressed to a similar committee, that gentleman explained at length his views upon the subject.

There is no doubt that cases will occur, for instance, as in the early working of a very fiery seam of coal, or in the re-opening of abandoned mines, infested with fire-damp, where the steam jet may be applied with advantage, but in such instances as these no great *quantity* of air is requisite; but as regards the amount of air to be obtained by the furnace and by the steam jet in comparison, the following quotation from a paper communicated to the North of England Institute of Mining Engineers, by its president, Mr. Nicholas Wood, seems conclusively to settle that point:—

"In conclusion, the practical result of all these experiments is, that within the limits or range of furnace ventilation, the steam jet acting as a *substitute* is attended with an increase in the expenditure of fuel of nearly 3 to 1, without any corresponding advantage, either in the steadiness, security, or efficiency of ventilation; on the contrary, from its economy and its efficiency in cases of emergency, the furnace is a more secure, more safe, and more eligible mode of ventilation than the steam jet. And with respect to the steam jet as an *auxiliary* to the furnace, the conclusion is, that the increase of the jets over the furnace is quite inconsiderable; that such increase is extremely unsteady, in some cases nothing at all, when the furnace is urged to its maximum effect, and in the ordinary working state of the furnace (supposing the furnace kept within its limit, so as to have adequate spare power in case of emergency), amounting to only about 2 or 2½ per cent.; that such increase is, however, attended with a loss of power or increase in the consumption of coal, as compared with the furnace, of nearly 3 to 1; and taking into account the uncertainty of its action, and that the increase of 2 to 2½ per cent. is only obtained when the furnace is about 10 per cent. within its maximum power, it is clear that the steam jet is inefficient as an *auxiliary*, when applied as a *substitute* for the furnace in the ventilation of mines." In conclusion of this subject, we give the following description of a somewhat novel application of the steam jet for the purpose of ventilating a coal mine, by Mr. F. H. Pearce, of the Bowling Ironworks:—The application is at present in operation in a pumping shaft, 120 yards in depth, the ventilation of which had been stopped by the water rising at the bottom of the pit during the time some alterations were being made in the pumps. The water having stopped the air courses, the pit, to within a few yards at the top, became full of the gas known to miners as black and choke-damp, which appears to have been discharged freely from some old workings, and thus it was rendered an impossibility for the workmen to descend until the removal of the gas had been effected, and a constant current of pure air produced in the pit. Mr. Pearce has succeeded in maintaining a perfect ventilation of the above-mentioned pit, simply by allowing a small jet of steam to issue into the atmosphere a few feet from the top of the pipes through which the water is forced up when the pumps are at work, and the pit can be worked with perfect safety. The workmen were enabled to descend 30 minutes after the steam had been turned into the pipes. The principle is exceeding simple. The jet of steam issuing from the top of the pipes produces in them a partial vacuum, which draws the foul air up these pipes, and thence out of the pit with very great velocity. The cost of applying the steam jet in the above manner is very trifling, and this method of ventilation will doubtless be found a very safe and useful one in many instances, particularly in sinking deep shafts. In addition to other advantages, wood or any other kind of pipes may be used. It requires little or no attention, no machinery to get out of repair, produces a powerful current of air, and can be regulated at pleasure. As the steam is discharged into the atmosphere above the top of the pit, it does not interfere with the men working in the shaft."

d. MACHINERY.—Several mechanical means of forcing air into mines, or of exhausting it out of them, have at various times been contrived, and in a few instances in this country adopted. On the continent, however, and more particularly in Belgium, where the furnace is considered to be less economical, and is forbidden by law in fire-damp collieries, and even associated with dumb-drifts is being abandoned, in order to be replaced by ventilators. (*Mackworth's Evidence, June* 23, 1853.) They are very generally applied to colliery ventilation.

Mr. John Taylor, of Tavistock, invented a form of air pump, which is thus decribed in Brewster's Edinburgh Encyclopdia:—"A large cistern is constructed of wooden staves, hooped with iron, circular, and from 6 to 8 feet in depth; this is nearly filled with water. Through the bottom of this vessel a pipe passes from the mine to be ventilated, and passing up through the water, is carried about a foot above it. Upon the top of this pipe is an air-tight valve, opening upwards; over this pipe and within the sides of the cistern, a cylinder of plate iron is placed, open at the bottom but close at the top, in which top an air-tight valve is placed, also opening upwards. This iron cylinder is made to move in a vertical direction by guides or sliders, and its upper end is attached to a lever or chain, which is moved either by a water-wheel or steam-engine. An exhausting machine of this construction may be made from the smallest size to be worked by the hand, to any requisite to be moved by machinery (vol. 14, 1820).

According to a statement made by Mr. Wood, at a meeting of the North of England Institute of Mining Engineers, on June 3, 1853, a machine of Mr. Struve's invention, having an areometer, 17 feet in diameter, and worked at from 7½ to 8 strokes per minute by a steam engine of 14 horse power, produced a ventilation of 22,000 cubic feet per minute, being $\frac{22}{25}$ths of its calculated effect. In addition to the above, may be mentioned the centrifugal ventilation of Mr. Brunton, the pneumatic screw of M. Motte, the windmill ventilation of M. Lesoinne, the spiral ventilation of M. Pasquet, the inclined vane fan of M. Letoret, the curved vane fan of M. Combes, the feathering fan of M. Lemielle, and the pneumatic wheels of M. Faboy; the chief of which are minutely described and illustrated in Mr. Mackworth's evidence, contained in the First Report from the Select Committee of the House of Commons, on Accidents in Coal Mines in 1857.

The whole of these machines are liable, however, to one insurmountable objection: their liability to derangement, and the consequently unventilated state of the mine until they can be repaired. The heat of the upcast shaft of a mine, ventilated by furnace, is such as to cause a considerable circulation of air for many hours after it has been extinguished; and a proper arrangement with regard to dumb-drifts for currents which might chance to be dangerously loaded with explosive gas, will preclude the slightest risk arising from their passing into close proximity to the fire.

That air, put in motion, has momentum in common with other bodies, no one will doubt; but that its momentum in mines is almost instantaneously overcome by the friction or resistance of the air channels, is equally true. In proof of this may be stated a fact, elicited during the application of the exhausted steam from an underground steam engine to ventilate Belmont colliery, where each stroke of the engine was distinctly observable in the workings by its effect upon the doors; and in describing the ventilation by Mr. Struve's machine (before alluded to), Mr. Wood stated that the pulsation of each stroke of the areometer piston was distinctly felt in the workings at a considerable distance from the shaft.

THE OBJECTS TO BE PROPOSED IN THE VENTILATION OF MINES.

There are three principal objects which ought to be proposed in the ventilation of mines; namely, the introduction of a sufficient quantity of air; its proper distribution; and the security of the arrangements to maintain this distribution and circulation. In the first place, the quantity of air to be introduced should be not merely that which is necessary barely to neutralize and carry off the explosive and noxious gases which are yielded under ordinary circumstances in the mine; but also to supply a sufficient volume to provide for the unusual emissions of them, which sometimes occur, and to dilute these to such an extent as to avoid danger; and at all times to afford a healthy atmosphere for the breathing of the workmen. In the second place, due regard must be given to the proper distribution of the air introduced, so that every part of the excavations of the mine may have its requisite circulation, and none be left stagnant for the accumulation of gas; to the conducting of that which is introduced, without waste, and without its coming in contact with the dangerous and noxious gases, to those parts where the men are engaged; and to the providing for its separate return or escape, or that of any portion of it, carrying off with it these gases, as soon as it shall have become anywhere perceptibly loaded with them, without again entering the working districts or coming in contact with the workmen or their lights. In the third place, the security and stability of the air ways, their freedom from leakage, and strength to resist the shock of an explosion, and also the regular and equable action of the motive power employed to produce the circulation, require attention.

In determining the requisite measures to effect these objects, it is necessary to consider the following subjects. The nature of the seam to be worked; its thickness and inclination; the character of the accompanying strata; the extent of the workings which are to be effected, and that of the surface of coal which will be exposed at one time in the excavations; the state of these works ings at different and future periods; and the number of workmen who will be employed.

The number of workmen to be employed is one of the most important elements in determining the quantities of air which ought to be introduced into a mine. The data which I have collected on this subject would induce me to assign an amount varying from 250 cubic feet per minute, in coal seams which are not fiery, up to 500 cubic feet per minute in fiery seams, as requisite for each person employed.

Attention cannot be too strongly called to the importance of measuring and recording, at stated times, the quantities of air passing through the different parts of mines; and that, not only in the ingoing and outcoming passages contiguous to the shafts, but also in those distant parts where the majority of the men are employed. It will be found that the volumes measured near the shafts often give erroneous results, if employed to estimate the state of ventilation in the more distant districts, on account of the leakage which occurs in the passage allowing a large portion of the air to return before it reaches the face of the workings. The investigation of numerous cases clearly shows that the greater part of explosions occur in collieries in which the defective supply of air, especially in the working districts, would become immediately evident, if submitted to measurement. The practice of ascertaining the exact quantities of air circulating in mines, especially if brought into comparison with the number of men employed, would also direct attention to the injury to health produced in numerous cases by insufficient ventilation.

THE MOTIVE POWER APPLICABLE TO COLUMNS OF AIR CIRCULATING IN MINES.*

The following subjects require to be considered in the next place; namely, the motive power applicable to ventilation in mines; the velocities of air currents, particularly as connected with the loss of effect from friction; the relation of velocity and friction to the area, form, and length of air passages; and the separate volumes into which the total amount of ventilation should be divided.

THE VENTILATING FURNACE.

The effective power of furnace ventilation (which from its general use, where large quantities of air are needed, may be taken as the standard of reference) depends on the height and sectional area of the ascending and descending columns. In deep shafts the diminution of temperature, in the upper part of the ascending column, is considerable, and reduces the ratio of effect due to the height. In shallow shafts the want of height in the column is not found inconvenient, as the loss of effect, from this cause, may be compensated by giving a larger sectional area to the shafts; whilst at the same time, the length or run of the air currents is generally so much shorter, in shallow mines, and the quantities of air required are also so much less, that the apparent objections to its use under such conditions are not regarded.

The furnace fulfils the most important requisites in motive power, by its efficiency, its uniform action, and the easy control of which it admits. The steam jet is inferior to it in some of these respects, but it is free from objections to which the furnace is open. The liability to derangement in all machines appears to preclude their use in ventilation, in other than exceptional cases. In mines of large extent it would be difficult, perhaps impossible, to withdraw the workmen, in case of breakage, before danger ensued. The comparative effect, from a given consumption of fuel, between the furnace and the most approved machines, is not favorable to the latter.

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* Blackwell's Report.

The objections to the furnace are, the possibility of its exploding foul returns from the mine, either when this state is permanent, or produced by a sudden emission of fire-damp, or caused by the derangement in the general system which follows an explosion; and also the inconvenience and damage produced by an elevated temperature in shafts applied to winding. The first objection, relating to the danger from permanently foul returns, has been met by feeding the furnace by a split from the intake air, or by returning for this purpose a part of the air which has only had a short run and contains little inflammable gas, while that part of the return air which is explosive is passed by a dumb drift into the upcast shaft; or, otherwise, by such an increased ventilation in the mine as shall sufficiently dilute all the returns from every district, and permit the whole to be passed over the furnace. The latter of these plans is in general preferable, not only from the improvement in the state of the ventilation which it necessitates, but also from its allowing the whole of the returns to be rarefied, and thus enabling a larger effect to be obtained from the increased temperature. The second objection arises from the possibility of large emissions of fire-damp suddenly rendering the return air currents explosive. In fiery seams, which are newly opened, especially when the goaves begin to be formed, it may be advisable to employ the steam jet, the waterfall, or some other motive power than the furnace. The last objection may always be obviated by an additional shaft applied to ventilation alone.

In examining the effective power of the furnace, and comparing the results obtained in different instances from given temperatures, the drag, or comparative friction, in air courses of varying sizes, forms, and lengths, must be taken into account. A comparatively high temperature, in the upcast shaft, is necessary to obtain the largest economic effect, since the amount of difference between that of the upcast and downcast is, up to a certain point, expended in counteracting the resistance from friction consequent on setting the air in motion. After this point has been passed, all additional increase in the temperature would be utilized, or produce a corresponding effect, provided the area of the air passages were proportionally enlarged, as the temperature ascends, so as to maintain a constant or uniform velocity in the air currents. But if this rate of velocity be an ascending one, from the area of the air passages being constant, the resistance from this cause increases so rapidly, that a rise of temperature in the upcast column gradually loses the effect which would be otherwise due to it. It will thus be seen that by modifying the form and area of these passages, a lower temperature in the upcast shaft connected with them may become more effective than a higher one, under different circumstances; or, in other words, a small effect, with a high temperature, may be the consequence of friction; a large effect with low temperature may be the result of the removal of this cause of retardation.

VELOCITIES OF AIR CURRENTS.

In considering the velocities of columns of air, in the shafts and air ways of mines, the question to be first proposed is, what are found in practice to be the rates attainable, without an excessive loss of power by friction. So many variable elements, namely, the sectional area, form, and length of the air ways, in connection with the rates of velocity in the air currents, being concerned in determining the actual loss from this cause, an exact expression of the rule which governs it cannot probably be given. It is evident, however, that resistance from friction increases much more rapidly than in the simple ratio of the velocity, and follows at the same time the inverse ratio of the sectional area, and the direct ratio of the length of the air ways which the currents have to traverse. The form of the air passages, in so far as their course approaches a straight line, or contains numerous curvatures, produces a great effect, especially with high velocities. The conclusion in practice should therefore be in favor of adopting a low rate in the interior of the mine, whatever may be the speed of the currents in the shafts, since from the shortness and directness of the latter channels, the rate in them is mainly to be determined by the degree of temperature which can be admitted in the upcast. The highest velocities which I have found in practice to be obtained in upcast shafts, which are also used for winding, are from 8 to 10 feet per second. This amount will depend not only on the temperature, but also on the area left free from the obstruction of winding apparatus. Shafts in which two bands works in opposite directions, and in which the action on the column of air, by one cage, is compensated by that of the other, admit a much higher velocity than when the whole area is nearly filled by a cage, or platform, moving in one direction. The increased temperature (sometimes averaging 140, 160, or 180 degrees) which can be given to the air, and the absence of resistance from the winding apparatus in those shafts which are used for the upcast current exclusively, permit a velocity of 20 or even 30 feet per second to be attained. In the interior of the mine, high velocities are inconvenient, and the loss from friction great, in consequence of the length of the air currents. In the main wagon and air ways, in which the whole of the ingoing or outcoming columns from different districts are united, it would be advantageous to give sufficient sectional area to keep the velocity below 10 feet per second, and a lower rate even than this would be preferable. In particular cases, however, I have found the velocity in a single district of the mine contiguous to a shaft may reach 20 feet per second. But even in large air ways, a velocity of more than 5 feet per second is productive of much loss by friction, as becomes immediately evident from the results of splitting a column of air travelling at that rate. A velocity of from 3 to 4 feet per second may be stated as the full speed desirable in the general branch ways and workings of a mine, except in such situations as those in which a large yield of inflammable gas is taking place from the whole coal.

RELATIVE AREA OF SHAFTS, AND OTHER AIR WAYS.

The relation between the sectional area of the upcast shaft and the aggregate sectional area of the air ways of the mine, is important, in those cases in which as large a ventilation as possible is required to be maintained. The following is proposed as a suitable rule; namely, that since, when this shaft is used for winding with double bands and open cages, a rate of velocity of from 8 to 10 feet per second may be obtained in it (which is equal to fully double the average rate that should be calculated on, in the air ways of the mine,) that, therefore, in this case, the aggregate sectional area of the latter should be double that of the shaft. If this shaft be not used for winding, but for the upcast column only, the velocity maintained in it may be from four to six times greater than that which should be found in the mine, and therefore, in these cases, equivalent proportions should be observed.

VOLUMES OF AIR CURRENTS.

The thickness of the seams of coal, and their yield of inflammable gas, must be considered, in order to determine the volumes of the different currents into which, in extensive mines, it is most fitting to divide the total quantity of air introduced. In seams about 6 feet thick, from 10,000 to 15,000 cubic feet per minute, according to the extent of the workings, will be found convenient volumes for a single current. But as a speed of from 5 to 7½ feet per second is requisite to pass these quantities through a sectional area of 35 square feet, and such velocities would be inconvenient in a current thrown on the working faces of the boards or stalls, it will generally be necessary to divide columns of this amount into two or three parallel currents, passing by that number of headways or air courses nearest to the face of the workings. It will be convenient to reduce these amounts according to the diminution in the thickness of the seam. In those which are thin 5,000 cubic feet per minute will be found in practice to be a suitable quantity; since, from the small area of air ways in such seams, much subdivision is necessary to obtain a large circulation. There ought always to be a superabundant supply of air at the face of the workings, so that any required quantity may be immediately directed by brattice to the places where the men are engaged.

AREA, FORM, AND LENGTH OF AIR WAYS.

It is important that air ways should be rendered as direct and short as possible. By a proper system of arrangement and division, the longest which can be required need not greatly exceed a length of 3 miles, in a mine extending over an area of 1,000 acres, nor in one of 2,000 that of 5 miles. Under the mode in which the air ways in it are arranged, the longest in any part of the mine could not exceed 2 miles. The average length would be much less. The length of the currents which traverse the working districts, or that section of each column between the intake and return air courses, is proportionally shortened. In the Newcastle district, before the system of splitting the air was fully introduced, the distance which the air travelled in one column in some mines reached the enormous length of 50 miles. At the present time, in other districts in which this system of splitting has not been adopted, the length of the air ways is even more disproportional to the extent of the workings. In such cases, the sectional area of the single column, in which the whole of the ventilation of the mine is forced through all the windings of intricate air ways, frequently only bears the proportion to the sectional area of shafts, of from one-fourth to one-tenth of a correct relation.

CAUSES OF EXPLOSIONS IN MINES, AND MEANS TO BE ADOPTED FOR THEIR PREVENTION.

The immediate sources of explosions in mines may be divided into four classes. First, the permanent yield or inflammable gas from the whole coal, as exposed in the roads and workings, which is in general of a constant amount. Secondly, a sudden and large discharge from the whole coal, or from the roof or floor of the seam. This is unusual, and seldom occurs, except in newly opened fiery seams. It may take place from the whole coal, as exposed in the workings, if it has not been previously drained by exploring and intersecting drifts; from the roof or floor of the seam in the goaves, especially when these are first formed; from the coal, or roof or floor in the drifts, on approaching or striking faults, or the soft coal contiguous to faults, or when the pressure of inflammable gas, existing in the seam, or in thin seams in the floor or roof, produces sudden rupture and liberation. Thirdly, stagnant fire-damp in the goaves of the mine, either on account of there being no channels for its outflow, or of the ventilation not being properly directed, or not sufficiently strong to carry the product of these goaves, on approaching their edges, into the return air courses of the mine, without their mingling with the working air. Fourthly, isolated roads or workings in which fire-damp is liable to accumulate, if secluded from the general circulation of the mine.

The first source of danger specified above may be guarded against by an increased ventilation. But in opening and working tracts of coal, from which there is a great discharge of fire-damp, the too rapid progress of the works is dangerous. This gas appears to exist in a state of condensation in coal seams, when first opened, and time is often necessary to allowit to relieve itself in some degree from the pressure which occasions its violent escape. For this reason, it is desirable that the main roads and ways of the mine, with cross intersections, should be kept considerably in advance of the workings, in order to allow this natural drainage to take place, as far as possible, before the coal is worked, and a large surface exposed.

The cause of danger referred to in the second place, is that which arises from sudden discharges. These are always possible when fire-damp is escaping under pressure, and ought to lead to much caution, when this is evidently the case, in seams of coal newly opened, and in exploring drifts. Increased ventilation may lessen the danger, but cannot remove it. The indications of a state of pressure on inflammable gas escaping from coal are immediately evident to the experienced eye, and their existence will point out the propriety of an adherence to the use of the Davy lamp in all such cases, as the only effectual safeguard. The exploring drifts, when there is a heavy discharge of fire-damp at their face, ought to be isolated in their ventilation from the other working districts of the mine, and may be preceded or accompanied by borings. A more extensive employment of the Davy, in conjunction with improved ventilation, will be found to be the only means by which the occurrence of accidents from fire-damp can be diminished in number.

With reference to the third source of danger above alluded to, namely, the accumulation of fire-damp in goaves which have been shut up, or along the edges only of which a current of air can be directed, and the liability of this inflammable gas to acquire pressure, or to fluctuate from various causes. These circumstances have long shown the propriety (which is acknowledged in the regulations of all well conducted collieries) of carrying on the workings, which are in contact with these goaves, with the Davy lamp, and not with naked lights. But in addition to this precaution, it is desirable to restrict as much as possible the size of the goaves by subdivision, and to provide return air courses, into which the fire-damp they yield may escape by its expansion, or its specific gravity, either alone, or by mixing with the ventilating current which has swept along the goaf, and which, after this contact, ought not to be used again in any other part of the mine, in which naked lights are employed. The provision of these return air courses, if the goaves are made to communicate with them by the necessary openings, in conjunction with that ventilation which may be directed along their edges, ought to prevent any appearance of inflammable gas in the air of mines, except at the face of exploring drifts. Dangerous goaves are those in which fire-damp is permitted to exist in a stagnant condition, or under that pressure which will be gradually communicated to it, when they are left without any channels for its escape, as it is yielded, or as it reaches their edges. In cases of an accumulation of stagnant fire-damp, the fluctuations to which it is liable are to be feared, even when there is no pressure upon it, as heavy falls, or the state of the atmosphere, may bring it suddenly in large quantities into the air currents. Wherever it can accumulate in goaves, to the extent of acquiring pressure, and such goaves are driven into, a sudden rush of gas is the consequence. A powerful ventilation sometimes becomes dangerous, when directed along the face of such goaves, as the mode in which the air current impinges on them, may be such as to have a tendency to draw a portion, but not the whole of the accumulated gas, out of them, and it may, from its fluctuation at different times, be carried to the upcast furnace in unusual quantities, and produce an explosion.

The fourth and last source of danger spoken of, in which, from inadvertence or misarrangement, a portion of the workings liable to the accumulation of fire-damp is secluded from the general circulation of the mine, admits of such easy removal, that it is only necessary to allude to it.

The examination of the various circumstances, to the occurrence of which explosions can be traced, has shown that discharges of inflammable gas occasionally take place in mines which cannot be provided for by ventilation only; but, in such cases, the condition of the seam, and the amount of pressure under which the exudation of fire-damp occurs, will afford a degree of warning, to the experienced eye, and suggest the propriety of obtaining the additional security afforded by the use of the Davy lamp. Attention has also been drawn to the fact, that in pillar workings, or wherever goaves are in process of formation which yield fire-damp, and are in contact with the working air, the necessity is already recognized, in well-regulated collieries, of adhering to the exclusive use of the Davy lamp, in those districts of the mine in which these circumstances exist.

These facts certainly appear to direct our consideration to the practical security, which long experience has proved to result, from the careful use of this lamp, even under conditions of the greatest danger; and to the inquiry, whether its more general adoption, as the light employed in coal mines, would not be practicable, and prevent many explosions.

In connection with this inquiry, it is desirable that two points should be kept in view. In the first place, the use of the Davy lamp must not be allowed to supersede good and complete ventilation. In the second, unless this lamp is used with care, and under strict regulations, it becomes a source of danger from the mistaken confidence it produces. A mixed system of lamps and naked lights in the same district of a mine, or the allowing of workmen to open their lamps at their own discretion, is extremely hazardous.

LOSS OF LIFE FROM EXPLOSIONS.

In considering the loss of life arising from explosions, the circumstances under which so much larger numbers of the persons involved usually perish by the after-damp, than by either the burning or concussions occasioned by the blast, demand the most careful attention.

Explosions are of two classes—partial, that is, confined to a particular district, or general, extending through the whole of the mine. If the first explosion be heavy, it is frequently followed by others, caused, either by the action of the flame on the surfaces of coal exposed, liberating by decomposition large quantities of carburetted hydrogen, or from the shock and rush of air which occurs, disturbing accumulations of inflammable gas in some other part of the workings, which again explode as soon as they become mixed with the air currents of the mine.

If the stoppings which divide the different districts and air currents in a colliery are weak, they are all overthrown by an explosion; at the same time the rush of air, and the inflammable gas formed or set in motion, spreads the action of the fire everywhere. The extent of excavations which stand open in some mines contributes greatly to this violence. The imperfect separation which is so often allowed to exist between the various districts and currents, arises from the fact, that the arrangement and means adopted have been devised with reference only to the management of the air, under the ordinary circumstances of its motion. The consequence is, that weak stoppings, or even doors, are employed to separate and guide the most important currents, such as the main ingoing and outcoming columns of air, the absolute division and permanent security of which involves the lives of all who are in the mine.

The greatest modern improvement in ventilation consists in the division of the works into districts; not only in order to afford purer air in each section, by a larger aggregate volume and a shorter run in the air currents, but for the purpose of isolation, in case of accident. To attain the latter object, the barriers separating these districts, and their system of air ways, must be of a nature not liable to derangement, which may, without difficulty, be effected.

The loss of life from after-damp is generally found to occur, to the largest extent, in the roads which the men have to traverse on their way to the shafts by which the mine is entered. This fact points out the necessity of making these roads the main intake air courses, and of securing these intake columns of air, both from the contact of fire-damp, and also from their being disturbed by the shock of an explosion, until they reach those points in the mine where they enter the workings in which the men are engaged. It is only in case of the permanence of the arrangements made to establish this division, and to conduct columns of pure air to the extreme districts at all times, that the men can escape after an explosion, or that help can be speedily conveyed to the survivors, who may be suffering from it, but unable to effect their own escape. The system of using the main roads for return air ways, in which the currents, after they have received all the explosive gases yielded in the mine, are brought or kept in contact with lights (and thus both propagating an explosion and cutting off every avenue of escape, since these roads are sure, under such circumstances, to be swept by the fire or speedily filled with after-damp), ought not to be adopted except in small collieries, in which inflammable gas is never seen.

The foregoing considerations also point out the strong necessity for two independent shafts in all coal mines; and of providing for the accessibility of the downcast shaft to all the men engaged. Subsequently to an explosion, it is generally impossible to descend or ascend in an upcast shaft, until after the lapse of some time, on account of its being filled with the after-damp.

If there be only a single shaft, and the division of the downcast and upcast currents be of a slight nature, such as by a brattice partition or pipes fixed in the shaft, the damage which is produced by an explosion generally prevents either escape or the rendering of assistance to the survivors. The number of bratticed shafts is fortunately diminishing. Where they are still continued to be used, it ought not to be permitted that any other light than the Davy lamp should be taken below the surface. The employment of a furnace for ventilation is objectionable in such cases.

OTHER INJURIES AND ACCIDENTS TO WHICH MINERS ARE LIABLE.

There is another class of injuries resulting from defective ventilation to which miners are exposed. The circumstances producing these injuries are slow in operation, and from their effects being disease, and not immediate and sudden death, their existtence has been little considered. A careful examination of the state of mines leads to the conclusion, that the ultimate loss of life is greater from this cause than even from explosions.

VITIATED AND FOUL AIR.

These effects are the result of an inadequate supply of air, which thus becomes vitiated and unfit for breathing, on account of its having lost its due proportion of oxygen, which is replaced by the formation of carbonic acid. This gas has its sources from respiration, the lights of the mine, the decomposition of small coal in the goaves, and of timber in the workings. Air in this state is also usually found to be loaded with carburetted hydrogen, yielded from the whole coal or in the goaves. Sulphuretted hydrogen, arising from the decomposition of pyrites, is sometimes found to be present, especially in coal seams liable to spontaneous ignition. The gases formed by blasting are also allowed to load the air of mines to a very injurious extent.

This state in the atmosphere of mines arises from the want of the necessary air ways, and other arrangements to discharge such portions of the air in circulation, as may have acquired this condition, and to afford a fresh and pure supply, at any part of the workings.

The air in the leading drifts, and in the extreme workings of mines, is often found to be in an injurious and dangerous state, from the carburetted hydrogen and carbonic acid yielded or formed at those points, not being diluted and removed by a proper circulation. This may be caused by defective ventilation generally, or only locally. The latter case is of frequent occurrence, and arises from the main air currents returning to the shafts by leakage, without reaching the distant parts of the mine, or from a want of the requisite means to carry the circulation fully up to the face of the drifts and works.

Those districts and seams of coal least affected by inflammable gas, are generally those in which the ventilation is allowed to be in this imperfect and injurious state, on account of attention not having been called so imperiously to the subject, as it is by the violent catastrophes resulting from explosions.

Asthmatic diseases, at an unusually early period of life, are the unfailing results of ventilation which is deficient in quantity.

In reviewing the cases of explosions in mines, of which the attendant circumstances can be ascertained, it must be admitted that the greater part have been the result of a clearly defective system of working and ventilation.

The larger part of these cases show defects, arising either from a want of a proper system in the management of the ventilation, or that of the necessary volume in the quantity of air supplied.

ON THE LIGHTING OF MINES.

In the working of mines, where we do not find any fire-damp, we may use throughout the whole of the excavations any species of illuminating power we please: the most usual being the tallow candle or oil lamp.

In copper mines the candle is chiefly used, except near the shafts where more light is requisite, and where in consequence oil lamps or gas lights are substituted.

The pit candle is commonly of small size, weighing from 30 to 50 to the pound; it ought to be made of clean ox tallow, with the wick small and of fine cotton.

In the Anthracite collieries, small oil lamps are used, which are carried about by being stuck in the front of the miners' caps.

When gas is used, it may either be manufactured underground, or conveyed down the shaft from a gasometer at the surface. When made underground, the heat from the fires beneath the retorts may be economically applied to aid the ventilation of the mine.

The repeated accidents caused by the explosion of fire-damp in fiery mines, rendered desirable some method of lighting them by an agency, incapable of communicating combustion to the surrounding atmosphere.

Sir Humphrey Davy, in 1815, after having tried without success Kunckel's, Canton's, and Baldwin's Phosphorus, and likewise the electrical light, proceeds in his Treatise on the Safety Lamp to give the details of the various processes and reasonings by which he eventually arrived at the construction of "the Davy," a lamp which, for simplicity and safety under proper management, is still unequalled, and which affords a fine illustration of the great advantage to be derived by practice from the aid of science.

"My first safety lamps gave light in explosive mixtures containing a great excess of air, but became extinguished in explosive mixtures in which the fire-damp was in sufficient quantity to absorb the whole of the oxygen of the air, so that such mixtures never burnt continuously at the air feeders, which in lamps of this construction was important, as the increase of heat where there was only a small cooling surface would have altered the conditions of security. I made several attempts to construct safety lamps which should give light in all explosive mixtures of fire-damp, and, after complicated combinations, I at length arrived at one evidently the most simple, that of surrounding the light entirely by wire gauze, and making the same tissue feed the flame with air, and emit light.

"In plunging a light surrounded by a cylinder of fine wire gauze into an explosive mixture, I saw the whole cylinder become quietly and gradually filled with flame: the upper part of it soon appeared red hot, yet no explosion was produced. It was easy at once to see that by increasing the cooling surface in the top, or in any other part of the lamp, the heat acquired by it might be diminished to any extent; and I immediately made a number of experiments to perfect this invention, which was evidently the one to be adopted, *as it excluded the necessity of using glass, or any fusible or brittle substance, in the lamp*, and not only deprived the fire-damp of its explosive powers, but rendered it a useful light.

"I found that iron wire gauze, composed of 1-40th to 1-60th of an inch in diameter, and containing 28 wires or 784 apertures, to the inch, was safe under all circumstances in atmospheres of this kind; and I consequently adopted this material in guarding lamps for the coal mines, where, in January, 1816, they were immediately adopted, and have long been in general use."

Every Davy, to be safe, should of course be in a perfect state: it should always be securely locked when in use, and furnished with a shield, which, in order to combine the necessary protection from currents of gas, by which the lamp is liable to be assailed in every direction, with the requisite transmission of light, should be made of glass or other transparent substance, and extend from the bottom to the top of the lamp, proper arrangements being made for the entrance of the air for the support of combustion.

Since the application of wire gauze by Sir Humphrey Davy, many lamps have been constructed, some of which display great ingenuity, the principal object of which may be stated as being the attempt to combine the safety of the Davy with the illuminating power of the candle.

Among the glass lamps may be mentioned the following:

1. The CLANNY lamp, which consists of a lower cylinder of stout glass surrounding the flame, and an upper cylinder of wire gauze of less diameter. In this lamp, the air to feed the lamp passes through the lower part of the wire gauze cylinder, down the inside of the glass cylinder, the burnt air ascending inside of the cold air current, and escaping through the meshes of the upper part of the wire gauze; this then is a lamp protected by a single glass.

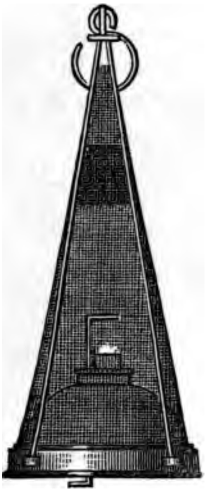
2. The MUESELER lamp is extensively used in Belgium, and does not differ much from the Clanny; but in this lamp there is a copper chimney to carry off the smoke from the wick of the burner, and to force the air entering through the wire gauze downwards between the copper chimney and the glass cylinder upon the flame of the burner, the air being admitted through the gauze at the top.

3. The BOTY lamp is another modification of this principle, having a glass cylinder with a wire gauze top; but in this the air is admitted through a ring of perforated copper at the bottom of the lamp. In other respects, it does not differ much from the Mueseler lamp.

4. The ELOIN lamp has also a glass cylinder: the air is admitted through wire gauze near the bottom of the lamp, and is thrown against the burner by a thin copper cap. No other air enters the lamp than that at the bottom through the gauze, and the space for admission of air being small, it is in consequence easily extinguished. Instead of having a cylinder of gauze for the top, this lamp has a copper or brass top, the exit for the vitiated air being at the top through wire gauze. This lamp has an argand burner, or flat wick: it gives a good light, but the top of the lamp soon becomes excessively hot.

5. A lamp patented by Dr. R. M. Glover and Mr. J. Cail, of Newcastle-on-Tyne, has a double glass cylinder, the air being

admitted from the top through wire gauze between the two cylinders, and, passing downwards, enters within the inner cylinder at the bottom of the lamp through a second wire gauze, by which it passes to the burner. The two cylinders are for protection in case of accident; and the air being passed between the cylinders, operates in keeping the external cylinder cool, and thus removing its liability to crack on exposure to a drop of cold water. The top of the lamp is wire gauze. This lamp, like the Mueseler, has also a chimney, by which, as stated in the specification of the patentees, "currents of air are prevented from affecting the steadiness of the light." This lamp, although a little complex, is the best of those dependent on glass for their safety; and, as a surveying lamp, placed in careful hands, I have no hesitation in pronouncing it one of the best lamps which has yet appeared.



6. A. Safety-Lamp, invented by Mr. W. P. Struvé, of Swansea, which we submit an engraved sketch of, has given very satisfactory results, from its use in some of the largest and fiery collieries in England. The sketch will convey a better notion of it than any written description, and it is only needful to add, that although the diameter of the gauze cylinder at its base is considerably more than that of the Davy, yet owing to the oil-box being placed within the gauze cylinder, instead of below it, and thus occupying a considerable portion of the internal space, the cubical contents of the cylinder does not exceed that of an ordinary Davy. The greater amount of cooling surface near the flame, and the less obstructed admission of air thus obtained, renders it practicable and perfectly safe to use a larger wick than in the Davy, whilst the combustion of the oil is much more perfect and the smoke very considerably diminished. The light emitted from this lamp has been carefully ascertained to be equal to that from three Davys, and owing to the conical form of the cylinder and the shape of the oil-box, it diffuses the light both upwards and downwards, as well as in every other direction, with less shadow than any other lamp that has been offered to the miner. From the more perfect combustion, the consumption of oil in this lamp but slightly exceeds that of the Davy, whilst

its simplicity of construction gives great facilities for keeping it in order and for repairs. It barely weighs 1½ lb. This lamp has been extensively introduced into many of the fiery collieries in South Wales. By this invention the accomplishment of the long-desired object of discovering a lamp which the miners would readily adopt in the place of candles has been effected; for we are informed that, wherever this lamp has been introduced, the miners eagerly accept it, and give it a decided preference, not only to the Davy or any other lamp, but even to candles. This fact is a most important one. The light being so much greater, and so much more diffused than in the Davy, there is no temptation to remove the gauze cylinder, and thus another fruitful source of evil is removed.

ACCIDENTS IN MINES.

The chief causes of accidents in mines are explosions of fire-damp, inundations, and falls of stone. There are also accidents arising from the breakage of ropes and chains, and the derangement of machinery.

Explosions may also arise from any of the following causes:

In working in the whole mine, candles being commonly in use, the air, in consequence of bad ventilation, may be gradually loaded with fire-damp to the firing point, in which case we will have a thorough blast, but this is a rare occurrence.

We may have a good ventilation, but a sudden outburst of gas from a blower may rapidly raise it to the firing point. This I believe to have been the cause of many explosions.

The ventilation may wholly cease, from the neglect of doors or injury of stoppings. In this case a district may soon be filled with inflammable air, which would probably result in explosion.

An accident happening to a safety lamp where gas is present may also cause an explosion.

And, as before stated, a good ventilation, mismanaged so as to cause the pressure of the air currents to be from the pillar or lamp districts into those worked with candles, may also be attended with fatal results.

The question is—Are any or all of these causes of accident controllable, and to what extent?

There is no excuse for any deficiency arising from a want of air; because it is quite sufficiently established that a quantity sufficient to meet all ordinary cases may be easily caused to circulate through the workings of a mine, the only requisites being a powerful furnace or the application of some other artificial means of producing ventilation, and, what are of the highest importance, spacious airways.

I believe that, notwithstanding the great quantity of air which we find in many of the collieries, a large addition could be made to it by due attention in this respect.

As regards the liability to explosion from blowers or "bags of gas," no amount of ventilation can prevent it; the only safeguard against such accidents consisting in the constant and exclusive use of safety lamps in the whole of the working places and returns, naked lights being confined to rolley ways. In fact, the probability is, that the greater the ventilation under such circumstances, the greater will the explosion be, on account of the more rapid and extensive formation of explosive compound.

To the safety lamp, then, alone must we look for the prevention of accidents in mines subject to sudden outbursts of gas, in which we may include all which are termed fiery mines.

The only method of preventing accidents arising from neglect of doors or injury of stoppings is, to have an active and intelligent superintendence over such matters. There are, or ought to be, in all fiery mines especially, overmen; who, if they cannot immediately detect any deficiency in their air current, are totally unfit for their situations.

An accident may happen to a safety lamp from a fall of stone; and, as far as possible to prevent this, the lamps should be used under strict regulations, which should be placed in the hands of the workmen and exposed in various places about the works.

By far the greatest fatality consequent upon explosions of fire-damp arises from suffocation occasioned by the after-damp.

Choke or after-damp consists by weight of 22 parts of carbonic acid, 18 of steam, which is condensed, and 112 of uncombined nitrogen; therefore we may call it more correctly a compound of 22 carbonic acid and 112 nitrogen. The specific gravity of such a gas will therefore be 1·066, or so little above that of common air that it may be assumed to form a uniform mixture with it.—*Williams's Combustion of Coal.*

The derangement of the air stoppings resulting generally from an explosion, causes the air to escape from the downcast to the upcast shaft by more direct channels than the workings where the accident has occurred, the consequence of which is, that in most cases, before the ventilation can be restored, the unfortunate sufferers have ceased to live.

The modes of operation which appear practically (at least to a great extent) to remedy this evil consist in having, when such an arrangement can be effected, the downcast and upcast shafts at opposite extremities of the workings; or in having distinct *pairs* of drifts for intakes or returns, these only being communicated together where rendered absolutely necessary; or, which amounts to the same thing, and possesses the advantage of applicability to existing and extended workings, in having the main returns driven in an adjacent seam of coal, when there is such at no great distance from the working seam. All the necessary artificial barriers between intake and return air courses should, of course, be of the most substantial description. By such precautions as these the force of a blast, by being more confined, might be more powerful; but this possible disadvantage would be many times overbalanced by their certain value in the facility they would afford to the speedy restoration of the circulation of air.

Inundations may happen from one or other of the following causes:—

By incautious workings beneath seas or rivers;

By communication with drowned workings;

Or, by the working out of pillars under drowned wastes.

With regard to the safety or otherwise of working beneath masses of water, this must altogether depend upon the situation, the strength and the nature of the superincumbent strata. There may be no danger in working within 20 fathoms of such waters, leaving proper pillars, the removal of which is, of course, out of the question. In the approach of drowned wastes, borings must always be made.

With regard to the other accidents arising from falls of stone, breakage of ropes, or derangement of machinery, they fall in a great measure within that category to which we must continue to a greater or less extent liable, in proportion to the number of people employed, and the amount of work they perform. There is no doubt that many accidents might have been, by proper precaution, avoided, but when we reflect that their causes are so numerous, we may well imagine, that even by the most careful, some circumstance, occasioning an accident, may have been overlooked.

All that can be done is, for every one in his own department to give the most unwavering attention to his duties, so that if, notwithstanding this, any accident should occur, he may be clear of that most severe of all punishments, self-condemnation.

In every colliery where inflammable gas is met with, a barometer ought to be placed near the shaft, and a daily register kept of the height of the mercury.

It may be stated, in conclusion, that few accidents need happen if we avail ourselves to the. utmost of those appliances of mining now in our possession. The ventilation we are now able to establish, although there is no doubt but that, in the course of a few years, we shall see it largely increased, is sufficient for most cases, if not for all. Casualties of explosion, so long as unprotected lights are used in the working of fiery mines, will inevitably occur. The machinery of mines, in proper order is safe, so far as the dependence to be placed on the strength and soundness of materials can make it; and ordinary accidents must be averted by carefulness in the general system pursued in carrying on the working of the mines.

ON BORING AND BORING APPARATUS.

Boring is an art that is very imperfectly understood, even by those connected with mining, it is also an art of great value and of no little degree of antiquity, but until within a few years it has not received that degree of attention it practically merits. It is surprising that in this country so little attempt has been made to improve and raise into a science the practice of boring.

Boring is chiefly employed in searching for coal and ironstone; but, whether applied to the discovery of beds of coal, ironstone, marble, clays, salt, gypsum, limestone, slate, springs of medicinal waters, or water for domestic purposes, brine springs, or even the existence of combustible gases, it must be conceded that the development of an art which must increase our facilities for the attainment of such information, is of great practical importance.

In all these respects we are thrown each year still more on the art of the Borer, by which we see through the earth's crust. There are few departments of engineering towards which so many paths of science tend; there are few operations of a mechanical kind, which require the union of so much ingenuity, patient observation, and unflinching perseverance combined.

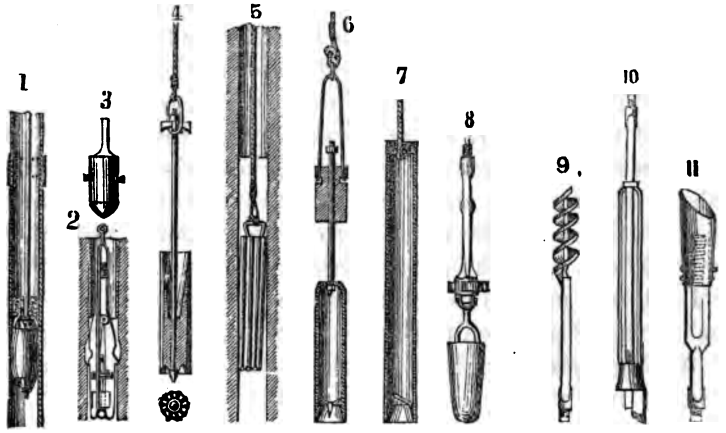
I will now proceed to describe some of the patents and principal processes practised in England, France, and Germany:

Among those who have improved the form of the cutting tools, we may mention Mr. Ryan, of England, who, about the year 1790, invented a tool by which cores or solid portions of the strata of the size of the bore-hole might be extracted, as well as Mr. J. Good, who in 1823, took out patents for various arrangements of this kind. Robert Breart, 1844; Wm. and Colin Mather, 1845; Wm. G. Gard, 1847; Charles Gotthelf Kind and Charles Alexis de Wendel, 1850; William Edward Schottlander, 1852; John Worthington and Fennel Allman, May, 1854; and

Colin Mather, October, 1854. In addition to these may be mentioned many known well-borers, although their improvements are not patented, and amongst them Easton and Amas, and D. Greenley, London; Fauvelle, Perpignon; J. F. Lane, Wilderz, Switzerland; Mulot and Son, Paris.

M. Breart describes certain improvements, by which the earth cut by the boring tools, at the bottom of the shaft, shall be immediately removed by a stream of water, in order to prevent the necessity for so frequently raising the boring-rod. He proposes to pass water down a hollow syphon pipe from a small reservoir at the top, so that as the water ascends the other limb of the syphon it may bring the particles of earth to the top. There are evidently many difficulties to be overcome in this plan, and as it does not appear to have been much used, they have probably been found to be insurmountable.

Messrs. W. and C. Mather's improvements of 1845, consist of a new arrangement of cutting tools in a boring head. A shell-pump, and a new method of giving a percussion motion to the boring instrument by means of a flattened rope round a winding drum, and actuated by a piston of a steam engine.



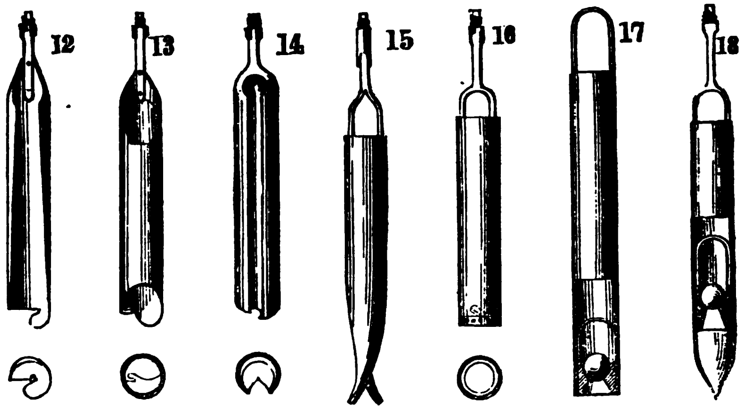
Mr. Gard's improvements consist in using a cylindrical shaft, with cutters attached, made with a single bevel, inclining inwards; above the cutters is a ball valve, fitting into a circular aperture, and so arranged that when the machine is worked the borings are forced through apertures up the cylindrical shaft above the cutters, and pass the ball valve, which brings the whole to the top, (see figs. 17 and 18.) This machine is worked by a rope, or chain, run round a fly-wheel.

Messrs. Kind and de Wendel's improvements consist of—1. A novel construction of boring tool. 2. A method of withdrawing a clod of earth, to ascertain the nature of the soil at any required depth. 3. A compound boring tool for shafts of large diameter. 4. A scraper for striking the soil to the centre of the tool. 5. Improvements in boring shafts of a cylindrical form, by the employment of oak cylinders and iron. The former are constructed like barrels, and retained in their proper position, one above the other, by broad rings or hoops of iron; and the latter have internal flanges, by which they are bolted together. By an ingenious arrangement of flanged teeth solid cores of hard material are bored, and brought to the surface. This machine is extensively used on the Continent, and its use has effected a considerable reduction in the cost of boring for mining purposes and geological research.

Mr. W. E. Schottlander's patent (figs. 9, 10, 11) consists in the use of boring-rods, fitted inside hollow cylinders—the boring tool being of a screw shape, and so attached to the machinery at the top of the well as to receive, by the turning of a winch-handle, a rotary motion round its axis, at the same time as it is progressively forced downwards. Additional rods and hollow cylinders can be attached as the boring increases in depth. For the purpose of removing the core of earth from the interior of the boring-rods, a double set of pipes may be employed, the inner ones being cleansed and returned.

Messrs. Worthington and Allman's patent claims the use of any kind of drills, bits, or tools, for boring when they receive a rotary or reciprocating motion, and the making of bits, drills, and boring tools, partly of iron and partly of steel, to prevent the necessity for frequent sharpening. The first and most important part of this patent is the same as Schottlander's.

M. Fauvelle's improvements were described in a paper written by M. Arago, and read by Mr. Vignoles, at the meeting of the British Association in 1846. The apparatus is composed of a hollow boring rod, formed of wrought iron tubes screwed end to end. The lower end of the hollow rod is armed with a perforating tool, suited to the character of the strata. The upper end of the hollow rod is connected with a force pump by jointed or flexible tubes, which will follow the descending movement of the boring tube for an extent of some yards: the boring tube is worked by a rotary movement, with a turning angle, or by percussion with a jumper; the frame or tackle for lifting, lowering, and sustaining the boring-rod are of the common kind; a column of water is sent down by the pump to the bottom of the bore hole, the water rising in the annular space between the exterior of the hollow boring-rod and the sides of the bore hole creates an ascending current, which carries up the triturated soil. The boring tube is worked like an ordinary boring-rod; there is, consequently, no occasion to draw up the boring tube to remove the debris, and the boring tool never gets clogged by the soil.



The jurors of the Great Exhibition of 1851 drew particular attention to the boring tools of Mr. J. F. Lane, of Wilderz, Switzerland. Water is introduced by means of hollow rods, and mixing with the powder or small dust formed in boring, is discharged through the tool by the blow of the latter in descending, keeping the bottom clear, and ready to receive the full effect of the tool. A boring of 1,300 feet has been made with these tools, and with a facility of which the old tools are not susceptible.

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The chief improvements in boring appear to have been made during the last thirty years, and although the art has been known in China during many centuries, and used to an extent which, for depth of workings, has not been exceeded in other countries, yet but one stereotyped system was invariably followed for all descriptions of rock.

The most simple method now employed is that by means of a tool similar in its actions to the common carpenter's auger: this tool is termed a wimble. It has, however, the evident fault of being only applicable to soft or yielding ground; its use is therefore extremely limited. Where great depths have to be attained, or hard ground passed through, a percussion arrangement is made use of. Under ordinary circumstances, this consists of a chisel-edged tool, similar to the common borer of the miner, attached to a series of iron rods, which, by means of male and female screws, are fitted into one another. These are lifted a certain height by a spring pole, to the end of which they are attached by a swivel joint. This arrangement may be worked by manual or other power, and is first raised and then allowed to fall against the bottom of the hole, whilst at each blow the whole set of rods are turned a certain portion of a revolution by means of a cross-head lever fitting tightly on the top rod. By a repetition of these blows, and gradually turning the boring bit in the hole, so that it shall strike various radii on the surface of the bottom, a certain portion of rock is reduced to powder; this mixes with water, forming a kind of paste. When it has accumulated to such an extent as to impede the action of the cutting tool, the rods are removed, by separately unscrewing them, and a *sludge bucket* to remove the powdered material is introduced in its stead. This consists of a short cylinder of the size of the hole, with a valve in its bottom opening inwards, which, being lowered to the bottom of the hole, the valve opens and the sludge or pulverized rock enters the cylinder, which is then drawn up; the valve, of course, closing on the bucket being elevated. The rods are subsequently re-introduced, and a similar series of operations again carried on.

Within a few years great advances have been made in the art of boring by the talent brought to bear upon it by Messrs. Kind, D'Œynhausen, Degousée, and Fauvelle, who have been eminently successful even where they have met with difficulties of such a nature as to entirely prevent the use of the common chisel-edged tool and iron rods.

To the use of continuous iron rods there are two great objections: first, their liability to break, from repeated percussions and vibrations through their entire length, which produce a molecular change in the iron, similar to that which takes place in railway axles, and which has been termed the "Fatigue of metals;" and secondly, this constant percussion and tremulous action of the rod lashes it against the side of the hole. When it is remembered that this action is repeated as often as 15,000 times in a day, and continued for many months without intermission, it will be readily understood that the softer portions of the strata through which the hole has passed will be liable to crumble and give way: this takes place in some instances to a considerable extent. Sometimes, also, portions of the rock get jammed between the rods and the sides of the hole, and thus entirely prevent their extraction.

To obviate this, M. D'Œynhausen has invented a slide on the rods. This is inserted at a height of five or six lengths of rod above the tool, so that it confines the shock of the fall to that portion of the arrangement. The weight of the upper rods is also counterbalanced, and they thus only serve as a support to the lower ones. The upper rods are also, for the sake of lightness, often made of wood, jointed together by male and female screws.

M. Fauvelle has introduced improvements in this art of a remarkably novel and ingenious nature. They consist in boring with hollow rods of a size considerably less than that of the hole; down these tubes is forced a stream of water, and by this means the loss of time consequent upon taking out the rods and introducing the sludge bucket is altogether obviated; since the downward current in the tubes, striking the bottom of the hole, forces to the surface the particles of rock removed by the cutter. There is also a great advantage gained by always having a clean surface for the tool to act upon. When boring in ordinary strata, this current is forced down the tubes; but when boring through sand or gravel, the current is forced down the outside, whilst the debris ascends through the interior of the tubes. By this means stones of the size of 2½ inches by 1¼ inch have been brought to the surface.

In point of saving of time some extraordinary results have been obtained by M. Fauvelle. A boring was made by this system at Perpignan, to a spring 186 yards from the surface, in July, 1846; the time occupied in reaching this distance was 140 hours of actual work, extending over a period of 23 days. A similar boring at the same place, carried on by a different system, occupied 11 months.

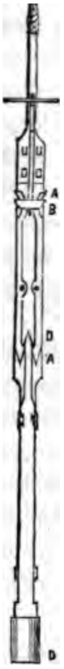
There are, however, objections to this plan, which have prevented its more general adoption; the first is the porosity of some kinds of rock, which causes the absorption of more water than the tube is capable of supplying; another is the action of large quantities of water entering the hole from between certain beds of rock. The first would prevent the debris from being carried to the surface, from the fact of the non-existence of the means; whilst the second would so far interfere with the current as to render its action only partial. In deep borings this system appears to be very inefficient.

The next system which we shall notice is that of M. Kind, who has introduced a number of most valuable improvements and has brought the art to greater perfection than any other engineer. Among M. Kind's improvements we may notice three—First, the use of light wooden rods; secondly, the employment of a "free fall" percussion tool; and thirdly, the method of obtaining a core or piece of rock of the size of the bore-hole, and of considerable length, which enables the operator to form a correct idea of the character and dip of the strata.

The advantage of the use of wood over iron rods is obviously their light weight, more especially when we consider that the bore-holes are usually filled with water; the wood itself soon gets saturated with moisture, and the iron screws and ferrules at the end of each render the whole mass of a greater specific gravity than the water in which it is immersed, only to such an extent as to allow of their falling freely through the liquid by which they are surrounded.

The free fall tool consists of an ingenious arrangement by which the bit is detached from the rods when they are lifted to the height necessary for the proper fall; it then drops by its own weight, whilst the rods follow separately, and when they have been again lowered to the neck of the tool, an opposite action to that which detached it causes it to be caught and held firmly while it is being again raised to the requisite height.

The "free fall" of the tool, with a length of rod attached to it, effects, in a more perfect manner, the object of D'Œynhausen's slide in removing from the wooden rods the injurious vibrations caused by the shock of the tool. The mode of action is explained by figs. 1 and 4, the first showing the manner in which the upper end of the piece (A D) is taken hold of by means of the fangs (C D), which work on the centres; the latter figure exhibiting the position of the various parts at the moment the tool is released. The tool is not shown, it is screwed into the bottom of (D). The fangs are made to bite by means of the ring and wedge (A B) being forced downwards. As this ring (B) is drawn up it immediately opens the fangs. The ring and wedge are attached to a leather piston (K), made about half an inch less in diameter than the bore-hole. The rods are moved up and down in the usual way. At the end of the upward stroke a sudden motion is communicated in the opposite direction; this causes the pressure of the water against the under side of the piston to lift the ring and open the fangs. The tool falls and the rods follow at a slower speed. Having descended to the proper point, a slight upward motion producing pressure against the upper side of the piston causes it to descend with the arm and ring and close the fangs. The tool is then lifted to its position for the second fall. The fall is from 1 to 3 feet; the number of strokes per minute, with manual labor, from 8 to 16, which can be increased by the application of machinery to 20 or 25. The weight of the falling tool from 8 to 10 cwt.; the rods are about 45 feet in length, made of wood 3 inches in diameter, with iron male and female screws to unite them.



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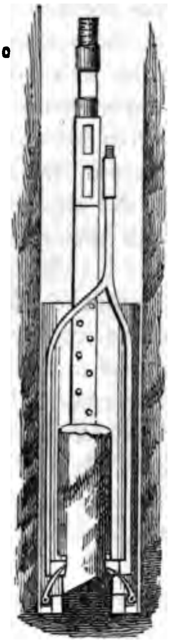

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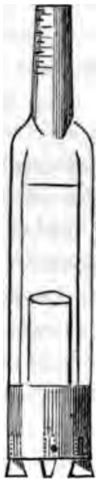

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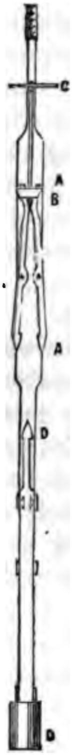

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Another improvement of M. Kind is the mode adopted by him to detach cores of 10 inches in diameter and upwards of 2 feet in length from the bottom of the bore-hole, so as to exhibit with the utmost accuracy the quality of stone passed through, the direction and amount of dip, and the actual thickness of the bed of rock or mineral.

The tools used by M. Kind for cutting and extracting cores are represented by figs. 2. and 3. Fig. 3. is a common borer, which being armed with fine chisels, by percussion makes a circular cut to the required depth. The second tool (fig. 2) is then lowered down to the bottom of the core thus formed, and the curved teeth slide down the surface of the core. The interior cylinder, which had previously been suspended by a cord, is then lowered so as to press the teeth inwards, a few vertical motions are given to the rods by which the teeth groove themselves into the core, and then by a jerk the core is detached and brought carefully to the surface.

M. Kind has likewise attempted borings of a size sufficient for ordinary shafts, and in this respect has also been successful. A shaft 14 feet in diameter was bored 300 feet in 9 months, at Moselle; another small one, 4 feet in diameter, was carried to a depth of 360 feet in 7 months, at a cost of $1 92 per foot.

The average cost of boring by various systems for holes of 750 to 1,200 feet in depth, where no extraordinary accidents have happened, may be thus given:

M. Degousée's system		$7 29	per foot.
Ordinary English	"	4 20	"
Chinese	"	3 84	"
M. Kind's	"	1 97	"

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